

TNA-Project-Yemen

Report II

Barrier Analysis and Enabling Framework (BA&EF)

March 2024

List of Acronyms

AREA	Agricultural Research and Extension Authority
BA & EF	Barrier Analysis and Enabling Framework
BRT	Bus Rapid Transit
CCU	Climate Change Unit
CO_2	Carbon Dioxide
CSO	Civil Society Organization
EADP	Energy Access and Development Program
ESCOs	Energy Sector Companies
FAO	Food and Agricultural Organization
GCF	Green Climate Fund
GJ	Gigajoule
GHG_S	Greenhouse Gases
GISM	General incorporation of seed multiplication
GOY	Government of Yemen
GW	Gigawatt
GWh	Gigawatt hour
HEIS	High-Efficiency Irrigation System
HEV	Hybrid Electric Vehicle
km / h	Kilometre Per Hour
LDC	Least Developed Country
LED	Light Emitting Diode
LT-LEDs	Long-Term Low Emission Development Strategy
LWSSC	Local Water Supply and Sanitation Corporation
MAI	Ministry of Agriculture and Irrigation
MCA	Multi-Citeria Analysis
MEE	Ministry of Electricity and Energy
MPIC	Ministry of Planning and International Cooperation
MW	Megawatt
MWE	Ministry of Water and Environment
MWp	Megawatt Peak
NAPs	National Adaptation Plans
NASS	National Agriculture Sector Strategy
NDC	Nationally Determined Contribution
NES	National Extension Service
NGO	National Governmental Organization
NWSSIP	National Water Sector Strategy and Investment Program
NSREEE	National Strategy for Renewable Energy and Energy Efficiency
PRS	Poverty Reduction Strategy
R&D	Research and Development
RE	Renewable Energy
TNA	Technology Needs Assessment
TNC	Third National Communication
UNDP	United Nations Development Programme

UNEP	United Nations Environment Programme
UNEP-CCC	UNEP Copenhagen Climate Centre
USD	United States Dollar
UNFCCC	United Nations Framework Convention on Climate Change
UN	United Nations
USAID	United States Agency for International Development

List of Contents

List of Tables

List of Figures

Annexes

Executive summary

This Barrier Analysis and Enabling Framework (BA&EF) report aims to assess barriers to the implementation of prioritized technologies in Yemen's energy, transport, water, and agriculture sectors as identified in the Technology Needs Assessment (TNA) project. This involves an exploration of potential measures to overcome the identified barriers, including incentives and other measures. Moreover, the report produces a comprehensive diagnosis of the most effective enabling frameworks for each technology, employing a systematic approach provided by UNEP-CCC, that integrates academic and industrial methodologies. This includes identifying financial and non-financial challenges, proposing measures to address them, and the refining of initial targets to support the wide diffusion and implementation of these technologies in Yemen.

From the TNA part 1, four technologies in each sector were prioritized using Multi-Criteria Analysis (MCA). These four technologies were also further prioritized to select two technologies for the BA&EF. The prioritization process was conducted based on the necessity of the technologies, the level of the barriers hindering their diffusion and implementation, paradigm-shifting potential, and finally the potential to address climate change issues in mitigation and adaptation. Based on the prioritization results, two technologies in each sector were selected. These eight selected technologies underwent the process of BA&EF to propose measures and find the enabling environment that will facilitate their implementation and existence in the market.

The first step of the BA&EF for each prioritized technology began with a systematic approach, suggested by the UNEP-CCC, focusing on the manual "Overcoming Barriers to the Transfer and Diffusion of Climate Technologies - 2nd Edition." It included a comprehensive desk study and literature review to analyse the barriers of the selected technologies, and to understand why the top two priority technologies in each selected sector are not widely adopted and why significant investments from both private and public sectors are not sufficient to widely use such technologies. Summaries of financial and other analyses of the technologies, provided by sector-specific consultants, were instrumental in the process of barrier identification, involving relevant stakeholders. Stakeholder questionnaires survey analysis and focus group meetings played a vital role in engaging stakeholders in the barrier analysis process, assisting in the identification of barriers, potential solutions, and enabling frameworks. Two analytical tools, root cause analysis, market mapping and logical problem analysis were employed in this context, engaging relevant stakeholders to analyse the barriers effectively.

Following the completion of the barrier analyses, various solutions, including economic financial, and non-financial measures, were assessed, and identified for each identified barrier. These solutions will constitute the foundation of the Technology Action Plan (TAP) development, earmarked as the final phase of the Project, slated for completion by mid-2024. This entire process was underpinned by the active participation and engagement of stakeholders through focus-group discussion workshops and results-driven group exercises. A critical step involved pinpointing all stakeholders and experts directly relevant to the assessed technology. The aim was to ensure the invited participants comprehensively represented all facets of the technology under review. Stakeholders were meticulously chosen from various sectors, including market and supply chain enterprises, policymaking and government bodies, research and innovation institutions, regulatory authorities, non-governmental organizations, and esteemed economists specialized in the relevant sectors.

A two-day workshop, held in Aden city from November 6-7, 2023, saw the attendance of 64 stakeholders from various backgrounds and entities. This workshop facilitated in-depth and productive discussions, enabling participants to validate the initial reports produced by TNA consultants, finally identify, and analyse barriers, and suggest suitable measures and incentives for the broad dissemination and implementation of priority technologies. The outcomes of the BA&EF process for each sector will be summarized in the following sections.

Energy Sector

For the energy sector, the barriers were analysed separately for each technology, even though, since both technologies (Off and On – and Grid Solar PV, and Wind turbine) are under renewable energy, they have a lot of common barriers. The most common economic and financial barriers for the two technologies were: high initial cost system, high interest rates, and Inadequacy of subsidy programs. The non-financial barriers that negatively influence the diffusion of the two technologies are technical, regulations, policies, and strategies, institutional, social, and awareness. The main technical barriers are related to the infrastructure, which is not ready to upload additional energy capacity generated from renewable energy sources. Besides, a lack of expertise who can handle renewable energy systems in terms of installation and operation on a large scale, especially for wind turbines, which is new for the local market. The regulations and policies in Yemen are not present, and the last strategy in this regard was in 2009. Despite the high potential of these technologies to address the energy shortage in Yemen, the absence of regulations, plans, and policies affects the rapid and wide expansion of these technologies in the power sector and local markets due to the absence of long- and short-term visions and targets. Institutional barriers play a key role in the presence of the technology in the market. The main institutional barrier is the non-existence of a national framework or body to lead and coordinate renewable energy investments in the country and monitor the progress and local market. The lack of awareness and knowledge minimizes the efficient benefits of these technologies from economic, environmental, and social perspectives, which limits their utilization on a wide range and large-scale projects.

The measures and incentives outlined and recommended for the energy sector can accelerate the deployment and dissemination of the two technologies. The combination of economic, financial, and non-financial measures could be a crucial first step in overcoming the barriers that hinder their application on both small and large scales. This combination could involve reducing or exempting import duties and developing innovative financial mechanisms that utilize both national and international financial channels. These mechanisms are to overcome the high initial and capital costs associated with these technologies. Additionally, reducing interest rates through accessible concessional loans and establishing national special funds for renewable energy are vital steps. For non-financial measures, a primary solution is establishing an independent institutional body acting as the main governmental institution for renewable energy and responsible for coordinating renewable energy investments. The deployment and dissemination of these technologies cannot be achieved without improving the current infrastructure, especially the national grids which need to be upgraded to smart grid systems capable of handling power supplies generated from both renewable and conventional resources. Furthermore, the development of new strategies, regulations, and policies that prioritize these technologies as potential renewable energy resources is essential. These strategies and regulations should align with programs to raise awareness and knowledge, thereby addressing technical and social challenges.

To effectively integrate renewable energy technologies, particularly solar PV, and wind turbines into the market, several key actions are necessary within the most viable enabling framework. Firstly, establishing an independent institutional body for renewable energy is crucial to lead and coordinate the promotion, strategy development, policymaking, and implementation monitoring of these technologies. Updating the renewable energy strategy to include specific targets for wind and solar PV integration is essential, ensuring it encompasses energy security, economic, environmental, and social benefits. The Government of Yemen (GOY) should create an investment-friendly climate to attract both domestic and international investments, giving priority to these technologies for climate finance projects in National Determined Contributions (NDC), National Adaptation Plans (NAPs), and Long-Term Low Emission Development Strategies (LT-LEDs), and aligning them with carbon market criteria under the Paris Agreement and other initiatives. Adjusting tax policies and subsidies to reduce the cost of renewable energy systems, especially focusing on rural and desert communities, is important. Developing plans for private sector engagement, integrating renewable energy into educational curriculums, expanding research and development, addressing social barriers through awareness programs, and strengthening the technical capabilities of national authorities are all critical steps. Additionally, considering the potential of hybrid PV-Wind systems in regions with suitable wind and sun conditions is valuable. Lastly, launching training programs for youth and entrepreneurs in the domestic manufacturing

of wind and solar components is essential, forming a cornerstone of the enabling environment for the widespread deployment of these technologies.

Transport Sector

Unlike the energy sector, the Bus Rapid Transit (BRT) and Hybrid Electric Vehicles (HEVs), face different barriers, although there are some commonalities in financial and non-financial barriers and measures. Financial barriers include the high cost of BRT projects which limits support from international aid donors and inadequate policies that hinder private investment. Economically, the low income of the local population and the negative impact on the small bus owners' income are significant issues. Additionally, existing legislation regulating the transport sector is not effectively implemented, marked by weak law enforcement and a gap between legislation and actual practices. There is also a notable lack of coordination and communication between government transport institutions, and the private sector is often excluded from decision-making in transport policies and development. The institutional capability and organizational potential within the transportation system are insufficient to keep pace with continuous advancements in transport technologies. There is a general reluctance to adopt new transport technologies. Furthermore, there is a lack of public information and awareness about the BRT's benefits. The poor infrastructure for mass bus transport poses a significant challenge for potential investors in the BRT project, compounded by the absence of standardization, codes, and certification for new transport technologies.

To overcome barriers to Bus Rapid Transit (BRT) deployment, several measures can be implemented. Firstly, new financial policies should be set to regulate financial institutions, alongside attractive financial and trade policies to motivate investment in BRT projects and encourage partnerships between the government and the private sector. Economic measures ought to include a just transition mechanism for small buses owners to mitigate possible adverse economic impacts caused by BRT introduction. This should be preceded by extensive assessments and studies evaluating the socioeconomic impacts of such a project, aiming to prevent any adverse economic effects. Additionally, establishing a legal and regulatory framework is crucial to creating a market for BRT and enforcing existing legislation/by-laws to regulate the transport sector. An effective communication and coordination mechanism must be developed between relevant government transport institutions and private sector stakeholders. Moreover, establishing professional institutions to support technical standards for new transport technologies like BRT is essential. Infrastructure development plans should be set to facilitate the introduction of mass public transport systems like BRT. Public awareness campaigns and information dissemination about the social, economic, and environmental benefits of BRT are also important. Finally, establishing certifications and standards, along with testing, demonstration, and training programs for new transport technologies, is necessary.

For hybrid electric vehicles (HEVs), economic and financial challenges include the relatively high cost of the vehicles, steep interest rates, and short loan periods, which make HEVs less viable for local consumers. Additionally, the lack of market and consumer incentives alongside weak market information diminishes HEV appeal. Non-financial barriers stem from the absence of clear policies, legislation, and regulations regarding the import and use of HEVs in the country. Poor coordination between relevant ministries and potential HEV suppliers significantly hinders the expansion of such technologies. Moreover, there is a notable lack of professional institutions with the capacity to manage and regulate new transport technologies like HEVs, compounded by bureaucratic procedures in government institutions. Other challenges include a shortage of qualified personnel for demonstration and maintenance services specific to HEVs, a general lack of confidence in HEV technology due to its unfamiliarity, and a widespread absence of information on the economic, social, and environmental benefits of using HEVs."

To address the identified barriers to the deployment and dissemination of Hybrid Electric Vehicles (HEVs), financial measures should include market incentives, such as reductions or exemptions from customs and excise fees on HEVs and their spare parts. Consumer incentives are also important, like reductions or exemptions from registration fees, annual road taxes, and other relevant charges. Furthermore, extending the loan period and reducing loan interest rates will decrease the overall costs of HEVs and boost ownership levels. In addition to financial measures, setting up legal

and regulatory frameworks is critical to creating a market for HEVs and promoting fuel-efficient vehicles. Establishing professional institutions to foster technical development and research and development (R&D) in transportation technologies is necessary. Training programs for administrative personnel regarding new transport technologies should be implemented. It is also important to create facilities that ensure compliance with standards, codes, certifications, and specifications relevant to HEVs. Lastly, disseminating information to consumers about HEV performance and its social, environmental, and economic benefits is crucial.

The enabling environment for both technologies must combine all the measures including the financial and non-financial ones. The government must implement various national economic and financial procedures to foster an environment conducive to introducing the Bus Rapid Transit (BRT) system and promoting the use and spread of Hybrid Electric Vehicles (HEV). These measures include establishing new trade policies and by-laws, as well as formulating tax, subsidy, and tariff policies. Additionally, regulating financial sector institutions and offering attractive public investment policies, which encompass commercial law and trade and financial practices, are crucial. Initiating capacity-building programs for relevant government authorities and institutions is also essential. This should occur alongside initiatives to enhance government procedure efficiency, and the promotion of trade associations, networks, organizations, and alliances. Setting technical standards, certifications, and codes for new transport technologies like BRT and HEVs is vital to prevent the adoption of low-quality technologies and infrastructure. To address the lack of information and awareness, the government should support publicly funded research, development, and training programs in the transportation system, and establish facilities for testing and demonstrating new transport technologies. Lastly, the government should develop a comprehensive plan for upgrading public mass transport infrastructure, including the rehabilitation of streets and roads. This plan should facilitate investment in technologies such as BRT and HEV, in alignment with socioeconomic and environmental studies highlighting the benefits of public mass transport.

Water Sector

Water, particularly in Yemen's main basins, is highly vulnerable to climate change, facing threats of depletion from overreliance on groundwater for agriculture and residential use. To mitigate this, Yemen must seek alternative and unconventional water sources, prioritizing desalination and rainwater harvesting. These technologies are crucial for addressing chronic water shortages and unsustainable groundwater dependency, though their adoption and maturity levels vary within Yemen.

Desalination is a modern technology that requires high capital costs and specialized engineering skills. It introduces a new source of water not previously available in Yemen's water budget. Despite this urgent need, Yemen has limited experience with desalination compared to neighbouring countries facing similar water scarcity issues. Significant barriers include the high financial costs, lack of technical capacity and market readiness and experience in Yemen where specialized components like membranes must be imported and are not readily available in the market. There is also an incomplete legal and regulatory framework governing water along with a lack of supporting institutions. Financial challenges involve a lack of access to loans and subsidies combined with high-interest rates. Overcoming these barriers is critical to establish desalination as a viable solution in Yemen.

To advance desalination as a utility-scale water source in Yemen, it will require a package of supportive policies, investments, and capacity-building measures enacted in parallel over the long-term. This includes legal and institutional reforms such as updated water law to establish clear regulations for plant operating standards, water quality guidelines, tariff structures, and environmental standards, all under an independent water authority. Securing international financing with concessional terms that acknowledge Yemen's conflict and economic instability is essential for funding desalination infrastructure. Exploring public-private partnerships with innovative financing can assess the feasibility of desalination projects across various aspects. Technical training programs partnering Yemeni engineers and suppliers with international experts and companies can help cultivate the specialized human resource capacity required for plant construction, operation, and maintenance. Reducing import barriers on desalination components like offering tariff exemptions or subsidies for reverse osmosis membranes may help lower capital costs.

Rainwater harvesting in Yemen, a community-managed and localized method, leverages indigenous knowledge and resources, especially in mountainous areas, to reduce evaporation and improve water access. However, economic constraints hinder the construction of capture systems challenges including limited access to loans, damaged livelihoods from conflicts, and inadequate subsidy programs. Additionally, the water law and policy framework does not adequately regulate rainwater harvesting. Limited studies on water quality and awareness amongst stakeholders remain low. Overcoming these institutional, financial and awareness barriers could unlock the potential of rainwater harvesting to enhance water security.

To overcome the barriers facing rainwater harvesting in Yemen's rural communities, it is essential to address financial, technical, regulatory, and social challenges. Measures include creating microfinance programs with favourable loan repayment terms to support cistern construction, Past projects demonstrated that domestic rainwater catchment can significantly improve water access and yields, raising awareness of its technical and financial feasibility and helping to develop a skilled workforce. Coordinating with non-governmental organizations and international donors to shift funding from temporary water trucking to sustainable cistern networks and watershed management can significantly boost rainwater management. . Incorporating provisions within Yemen's water law that delineate and protect customary rainwater rights while establishing use guidelines regarding public health, equity and environmental protection standards enforced through participatory governance structures has the potential to formally validate rainwater's role within integrated water resource management planning.

Agriculture Sector

Yemen's agriculture is vital for food security and livelihoods, and it faces challenges from climate change, including droughts, soil degradation, and water scarcity. Innovative technologies like terraces for soil conservation and drip irrigation for efficient water use are seen as key to mitigating these impacts. Despite their potential to enhance resilience and sustainability, the adoption of these technologies encounters significant challenges.

Drip irrigation technology faces significant economic and financial barriers, including high costs and lack of investment, which hinder its adoption and scalability. Non-financial challenges include inadequate standards, poor policy support, and insufficient coordination among stakeholders. Additionally, low community awareness and technical skills impede its widespread implementation.

To overcome barriers and enhance the technology's implementation and maintenance, a comprehensive set of economic and financial measures are proposed. This includes encouraging microfinance institutions and the private sector to provide support to farmers through a very low concessional loan. Additionally, a crucial non-economic measure involves the implementation of an awareness program among all relevant stakeholders. and updating existing legislations, policies, and establishing integrated coordination committees at both national and sub-national levels. Encouraging technical and vocational education is an additional measure to enhance the overall technical capabilities of stakeholders involved in drip irrigation technology.

The Terraces is a traditional Yemeni agricultural for soil management and conservation, faces both financial barriers like high cost, a weak market demand, and non-financial barriers, including the absence of well-defined policies, strategies, a coordinated mechanism involving relevant government institutions, the private sector, donors, and local communities, and dedicated research and studies. These economic and non-financial barriers collectively impede the effective adoption and integration of Terraces into the agricultural activities.

Additionally, fostering community enterprises, enhancing coordination, and providing technical support are key. Climate adaptation measures, incentives for local involvement, and integrating technology into education and research aim to ensure the successful integration of Terraces in agriculture.

In order to enhance the adoption of Terraces technology, a comprehensive series of both economic and financial measures have been proposed. These measures include the strategic direction of government and donor support soil conservation and terrace rehabilitation, formulation of investment policies and legislation, investment in awareness and knowledge programs. Furthermore, support is proposed for the creation and activation of community-based enterprises and initiatives. On the non-financial measures, tailored policies and plans for the preservation and reclamation of agricultural lands, establishment effective coordination channels between local communities, the private sector, and government institutions. To augment the technical support framework, the capacitation of the Agriculture Research and Extension Authority is advocated. Additionally, there is a recommendation for the design and implementation of climate adaptation interventions to mitigate soil erosion and terrace degradation. Non-financial measures also involve creating incentive mechanisms to attract local engagement and encourage the preservation of terrace lands, encouragement of the academia and research institutions to delve into research and studies, establishment of a platform for data and information sharing within the Agriculture Research and Extension Authority, and the implementation of knowledge and awareness-raising programs.

integrating these technologies into national laws and policies, and addressing economic barriers through investment policies and incentives. Enhancing governmental and community technical skills, incorporating technology education, and fostering stakeholder coordination are key. Establishing data-sharing platforms and engaging the private sector to supply agricultural technologies, as well as activating support mechanisms like microfinance for small farmers, are essential steps to promote technology adoption.
Creating an enabling framework for the widespread development and diffusion of Drip irrigation and terrace technologies in Yemen requires a comprehensive strategy. This includes formulating policies for direct international funds to agricultural technologies, integrating these technologies into national legislations, strategies, and policies, and addressing economic and financial barriers through investment policies, and incentives. Strengthening the technical capacities of governmental and community-based associations. Integration of technology issues into the education system, coordination and awareness programs, establishing a comprehensive database for data and information sharing, engage the private sector to support agricultural technologies. Finally, activating agricultural support mechanisms, particularly microfinance for small farmers, is vital for facilitating the adoption of agricultural techniques.

Finally, the measures and enabling frameworks for all the identified technologies in the selected sectors begin with political stability and peace-making. The current national circumstances in Yemen have a detrimental impact on all efforts to address climate change across various sectors. Consequently, the proposed measures must be seriously considered by the government and other stakeholders. Moreover, there is a multitude of additional actions that the government can undertake to foster an enabling environment, facilitating the widespread deployment and diffusion of these selected technologies country-wide. By prioritizing these measures, Yemen can pave the way for building resilience against the adverse effects of climate change and move forward into low-emission development pathways.

1. Introduction

1.1 Summary of the Outcomes from Phase I (TNA report)

The first report was produced from the activities of the TNA project in Yemen (Phase 1), which is implemented through the UNEP Copenhagen Climate Centre (UNEP CCC), and UNOPS and executed by the Environment Protection Authority through the Climate Change Unit (CCU). The TNA activity was systematically conducted through a country-driven process, involving all relevant stakeholders and considering national sustainable development priorities. The national stakeholders were involved in the first phase of the TNA Project in two rounds of consultation. In the first round, the launching of the TNA project in Yemen took place on January 2022 where the approach and work of the assignment were presented and discussed to obtain feedback from stakeholders on them and brainstorm and identify relevant pools of stakeholder groups to involve in the activities and discussions of the project. In the said workshop, three exercises were conducted involving all attendees. The first exercise was for the selection of priority mitigation and adaptation sectors for TNA activities, which was based on conducting a dedicated multi-criteria analysis (MCA) exercise prepared purposely for this step utilized in addition to the standard MCA form proposed by *UDP* for selection of priority technologies. The two MCA exercises revealed that the top two priority mitigation sectors for climate change technology needs in Yemen are *Energy* and *Transport. On* the other hand, the top two priority adaptation sectors were *Water* and *Agriculture* based on the selection process by stakeholders representing all mitigation and adaptation sectors in the country. This conclusion was not unexpected in light of the status of the energy and transport sectors as the two most emitters of GHGs in the country, their critical implications concerning sustainable development, and their potential for green transition into low-emission pathways. The same conclusion is valid for the water and agriculture sectors as they are the two sectors most vulnerable to climate change in Yemen as shown in the extensive assessments conducted in some national studies, mainly the TNC 2018 (Environment Protection Authority, 2018).

In round two of the stakeholders' involvement process of phase I of the project, *Mitigation and Adaptation Technical Working Groups* were invited to bilateral meetings, small working sessions, and workshops to discuss and prioritize technologies of each priority sector based on the set criteria for each sector. Results of the four MCA exercises revealed the following top four technologies out of the long initial rosters of assessed technologies in each sector assessed in terms of priority: the top four mitigation and adaptation technologies are presented in *Table 1-1*.

Table 1-1:The top four ranked technologies for Yemen's mitigation and adaptation TNA.

Rank/ TNA Sector	Mitigation		Adaptation	
	Energy	Transport	Water	Agriculture
Rank 1	LED Lighting	Bus Rapid Transit (BRT)	Saline water desalination	Irrigation saving techniques.
Rank 2	Off-grid and On-grid PV systems	Improving By-Roads	Rainwater Harvesting Techniques	Water harvesting and storage technology for agricultural purposes
Rank 3	Wind Turbines	Hybrid Vehicles	Diversion facilities and channels	Agriculture soil management and conservation
Rank 4	Solar Water Heating	Fuel-Switching to Gas	Wastewater recycling and reuse	Reuse of treated wastewater and greywater-

1.2 Prioritization of the Selected Technology Options for the BA&EF

The shortlist of the top-ranked technologies for each sector resulted from Phase I of the project and was taken to the next step and considered the entry point for Stage II of the project (BA&EF). The selected technologies are important to address climate change issues in the respective sectors and some of them have already been used in the country for decades, while others have just been introduced recently. The selected solar energy technologies for mitigation in the

energy sector are already and significantly used and available in the market except the wind turbines. Due to the blackout of the national power plant used to generate electricity for residential purposes, the Yemeni people to meet their energy demands, used efficient technologies, like LED lighting and Solar water heating, and renewable energy resources, particularly solar energy. However, some of these technologies still need a lot of work to enhance their effectiveness in addressing the climate change issues, especially, the renewable energy resources which showed high potential for addressing the electricity shortage in Yemen. Thus, identifying the barriers and creating an enabling environment is an important step to diffuse these technologies into implementation. The same thing goes for the transport sector, as people during the crisis started to import hybrid vehicles to reduce fossil fuel consumption due to the increase in fuel prices, and scarcity in the local market. Despite that, regulations, legalizations, and some institutional arrangements are needed to spread these vehicles in the market systematically. The options that need some modification and upgrade in the transport infrastructure will be difficult to achieve at least within the coming five years due to the weak institutional capacity and lack of finance because of Yemen's ongoing political and economic crisis. Meanwhile, BRT technologies are highly needed in the market, as these types of projects are attractive to private sector investment if the enabling environment is found.

For adaptation technologies, it can be noticed there are some joint options between agriculture and water. This is because of the interlinkage between water and agriculture, especially in climate change issues, as the impacts of water scarcity will lead to degradation in the agriculture sector. Therefore, reducing the dependency on groundwater for residential, commercial, and agricultural purposes must be reduced by finding innovative options that can provide traditional and renewable water resources. For this reason, it can be noticed that all the technology options in the water sector serve the purpose of reducing the water supply from the groundwater. Among all the technologies in the water sector, saline water desalination is a crucial option to address water basin depletion in the coastal zones. Rainwater harvesting is necessary in the northern highland areas of the country, which have experienced significant changes in rainfall patterns, in the last few decades, in the form of heavy and short rainstorms leading to flash floods without benefiting from such large amounts of water for agricultural and other purposes due to the limited water harvesting structures.

For agriculture, the enhancement of irrigation systems can strengthen the adaptive capacity of the agriculture sector against water shortage and drought. The same thing goes for rainwater harvesting and water reuse. The option of soil management is important as agricultural lands are affected by climate change impacts such as drought, floods, and desertification.

Since it was found to be difficult to analyse the barriers and identify measures for the four technologies in each sector, a further prioritization process was needed. The final prioritization was conducted based on a multi-criteria analysis (MCA) using specific criteria including the necessity of the technology, Level of the barriers, Paradigm-shifting and climate potential in order to translate the selected priorities into implementation to address climate change issues in the identified sectors. For this purpose, out of the top four selected technologies for each sector in Phase 1, two technologies have been chosen for the second phase (BA&EF). To rank the two most important technologies, the four options were examined against the mentioned selection criteria for adaptation and mitigation and ranked through a Multi-Criteria Analysis (MCA) exercise, using a scoring system of 1 to 5, with 1 being "low important" and 5 being "very high important." The final selection is seen in *Table 1-2* and *Table 1-3*.

Table 1-2: Final prioritization of the technology options in mitigation sectors

Sector	**Technologies**	**Criteria**				**Total Scoring \20**	**Ranking**
		Necessity of the Technology	Level of the Barriers	Paradigm-Shifting Potential	Mitigation Potential		

Energy	LED Lighting	4	1	3	2	10	3
	Off-grid and On-grid PV systems	5	4	4	4	17	**1**
	Wind Turbines	4	5	4	4	17	**2**
	Solar Water Heating	3	2	2	2	9	4
Transport	Bus Rapid Transit (BRT)	4	5	3	3	15	**1**
	Improving By-Roads	2	5	3	3	13	3
	Hybrid Vehicles	4	3	4	3	14	**2**
	Fuel-Switching to Gas	4	3	3	3	13	4

Table 1-3: Final prioritization of the technology options in adaptation sectors

Sector	**Technologies**	**Criteria**				**Total Scoring\20**	**Ranking**
		Necessity of the Technology	Level of the Barriers	Paradigm-Shifting Potential	Adaptation Potential		
Water	Saline water desalination	5	4	4	4	17	1
	Rainwater Harvesting Techniques	4	2	3	3	12	2
	Diversion facilities and channels	3	3	2	2	10	4
	Wastewater recycling and reuse	3	3	2	3	11	3
Agriculture	Irrigation saving techniques.	5	3	4	4	16	1
	Water harvesting and storage technology for agricultural purposes	4	2	3	3	12	4
	Agriculture soil management and conservation	4	3	4	4	15	2
	Reuse of treated wastewater and greywater-	4	4	3	3	14	3

From the above tables, the selected technologies for the BA&EF phase are as follows:

- **Mitigation**

a) Energy:

1. Off-grid and On-grid PV systems.
2. Wind Turbines.

b) Transport:

1. Bus Rapid Transit (BRT).
2. Hybrid vehicles.

- **Adaptation:**

a) Water sector:

1. Saline Water Desalination.
2. Rainwater Harvesting.
3.

b) Agriculture Sector

1. Irrigation saving techniques.
2. Agriculture soil management and conservation.

These eight technologies for the four sectors are examined under BA&EF phase to assess barriers, obstacles, and limitations hindering the wide dissemination and deployment of such technologies, to outline the required measures (incentives) to overcome such barriers, and to outline the enabling frameworks to maximize and enhance the wide spreading of such technologies effectively and systematically in the long run to address climate change in Yemen.

1.3 Barrier Analysis and Enabling Framework (BA & EF) Process and Steps

The objective of this report is to outline the outcomes of a detailed analysis of barriers for each selected technology, along with exploring potential interventions (like incentives or actions) to tackle these barriers. This effort also included evaluating the most suitable support structure for each technology and the collective technologies at a sectoral level. Upcoming chapters will reveal the identified barriers and measures for each primary technology within the selected sectors, utilizing a systematic approach reinforced by methodologies and best practices derived from scholarly literature and recognized industry norms for such evaluations. The methodology involved initially setting preliminary goals for each sector, followed by the identification of both financial and non-financial barriers. After this step, solutions and incentives to mitigate these barriers were proposed. The initial targets were then reassessed and fine-tuned based on the insights from the barrier analysis and the formulation of the enabling framework.

After the final prioritization of the four selected technologies resulted from Phase 1 and identifying the two technologies for Phase 2 as described in section 1.2 above, the first step of the BA&EF procedure for each prioritized technology was the use of the tools recommended in the guidebook *"Overcoming Barriers to the Transfer and Diffusion of Climate Technologies* (Ulrich & Hansen, 2015). The procedure was first to identify and decide on the classification of a particular technology, i.e., market or non-market good, and whether it is a "*consumer*" or "*capital*" good (for market goods) or "*publicly provided*" or "*other non-market"* (for non-market goods) as seen in *Table 1-4*.

Table 1-4: Classification of the Technologies

Technology category	Mitigation		Adaptation	
	Energy[1]	Transport	Agriculture	Water
Market goods	Off-Grid and On-Grid PV Systems	Hybrid Vehicles	Drip and Sprinkling Irrigation	Saline Water Desalination[2]
	Wind turbine			

[1] The energy sector technologies can be market goods for the small scale, such as the residential purposes or non-market goods for the large scale (publicly provided goods)

[2] Saline water desalination can be a market good for small scales, which is being implemented in some areas around Yemen. The large-scale desalination is a publicly provided good.

Non-Market goods	Off-Grid and On-Grid PV Systems	Bus Rapid Transit (BRT)	Terraces (Soil Management)	Saline Water Desalination
	Wind Turbine			Rainwater Harvesting

The barrier analysis of the proposed technologies was conducted based on, as a first step or initial work, an extensive desk study and literature review. Then, a deep analysis of policy papers reports, and other pertinent documents to identify the primary reasons behind the limitation of widespread and the limited use of these technologies, as well as the reasons for weak investment by private and public sectors. The desk study assessed the economic (economic and financial barriers), environmental, social impact, and institutional capacity of the selected technologies. However, due to the unstable economic and political situation of the country, several factors are affecting the market, particularly inflation and fluctuation of the technology prices maximizing the difficulties in carrying out the economic assessment and market mapping. Thus, the risks of investing in such technologies on a large scale have become very high and resulted in a very simple market. Therefore, prior summaries of proper financial and other assessments of the selected technologies by each sector's consultant before conducting the barrier identification process were also of great value for the barrier decomposition process. As an example, the conducted feasibility analyses illustrated the cost of capital, and why the cost may be considered too high for the public or potential investors. Thus, segmenting the barrier 'cost of capital' into its barrier elements and further into their dimensions was obtained from the feasibility summaries prepared by the consultants. Two specific tools were useful in conducting the analysis of the decomposition of barriers: the *problem tree analysis, the marketing* map the *solution tree*, both of which were used for each technology. After conducting the barrier analysis part, several measures (solutions) were identified for each barrier (economic and financial measures and non-financial measures). These tools facilitate the analysis of all the possible barriers and help to comprehensively cover all the possible barriers and select the potential measures.

All the above steps were aided by conducting dedicated stakeholder participation and engagement meetings in the format of surveys and questionnaires, bilateral meetings, small working sessions, focus-group discussions, workshops, and results-oriented group exercises. Very careful identification of the to-be-invited representatives of stakeholders to the BA&EF consultation workshop was carried out in preparation for the workshops. The purpose was to identify all directly relevant active stakeholders and experts to the particular technology under assessment so that they cover all aspects of the assessed technology. Such representative stakeholders were from market and supply chain involved companies, key players from policymaking/government, research, innovation and technology development (incubator) institutions, regulatory and governance parties, representatives of NGOs and farmers and Water Users Associations as well as competent and well-known economists in each particular sector. A validation workshop for this phase was held on 14 March 2023 to carry out the final prioritization, identify the final list of the selected technologies, and agree on the approach to BA&EF finalization. After the workshop, a series of activities were implemented such as desk review, bilateral meetings, site visits to the markets and selected locations in which technologies are applied, and small individual working sessions with the most relevant stakeholders. All these activities were concluded on an initial report to be discussed further in details in a focused workshop with all the stakeholders. Finally, after the preparation of the initial reports for each sector, a focused two-day workshop (one adaptation and one mitigation) was held in Aden City from 7 – 8 November 2023 (agenda is presented in Annex I. A total of 60 participants from stakeholders attended the workshop (attendees' roster sheets showing the affiliation of participants and the sector they represent is posted in Annex II representing all stakeholder categories mentioned above.

Figure 1-1:The Validation Workshop held in 7th ,8th, November 2023

1.4 A brief Step-by-Step of the BA& EF Process Followed

The steps to carry out the BA&EF took almost 10 months to complete, and all these steps are summarized in the diagram (Figure 1-2)and followed by the description below:

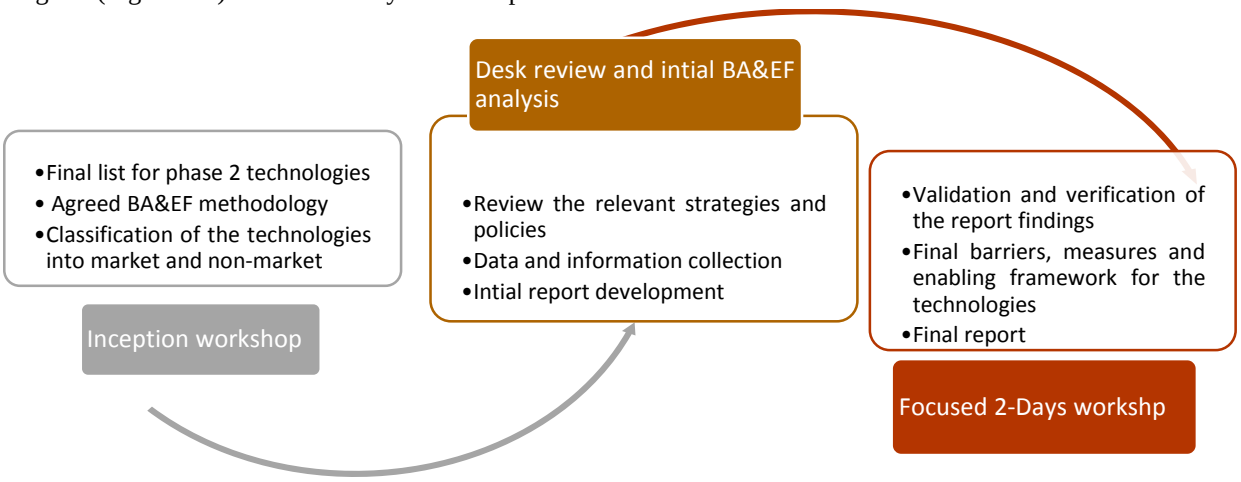


Figure 1-2: Process of BA &EF

The detailed process is as follows:

- Identification and analysis of barriers to the transfer and diffusion of climate technologies (both market goods and non-market goods) to establish a sufficient basis for developing measures to overcome them (translating barriers into solutions).
- Identifying barriers was perceived as tracing the reasons that are obstructing the transfer and diffusion of technologies.
- The primary task was to understand the nature of the individual barriers and the relations between them, determine which barriers are important, and identify barriers that are easier to remove.
- Understanding the barriers for transferring and diffusion of climate technologies was the key step to design the appropriate portfolio of measures to overcome them. This also helped to assess the costs and benefits of measures.

- General steps in identifying and analysing barriers were:
  - ✓ Organizing the process
  - ✓ Screening of barriers
  - ✓ Listing all identified barriers.
  - ✓ Selecting the most essential barriers
  - ✓ Decomposing the selected essential barriers
  - ✓ Logical deduction of barriers (problem tree)
- Categorizing of barriers into major thematic categories:
  - ✓ Economic & Financial
  - ✓ Market Conditions
  - ✓ Legal and Regulatory
  - ✓ Institutional and Organizational Capacity
  - ✓ Human Skills
    - ✓ Social, Cultural and Behavioural
    - ✓ Information and Awareness.
    - ✓ Other (environmental impacts, physical infrastructure conditions)
- For market-goods technologies (consumer goods and capital goods), which are expected to be diffused in large numbers under market conditions, the market-mapping technique was used to identify market barriers more systematically.
- Screening Barriers
  - ✓ Barrier identification resulted in a long list of barriers gleaned from various documents, interviews and/or the open-minded and nonselective recording of all ideas suggested by workshop participants.
  - ✓ When all the conceivable barriers have been identified, they were screened according to their significance. Workshop participants argued for and against the listed barriers to reach an agreement by consensus or majority;
  - ✓ Most important was to identify the essential barriers – that is, the barriers that definitely need to be addressed for technology transfer and diffusion to occur – as well as the non-essential barriers that are to be discarded and subsequently ignored.
  - ✓ Barriers were also sorted according to who has the power to do something about it and who is driving change: e.g. the national government, local authorities, or power utilities.
- Measures to overcome barriers.
  - ✓ Having established a thorough understanding of the barriers to the transfer and diffusion of technologies, the next step was to analyse how these barriers can be removed or overcome.
  - ✓ In this procedure followed (based on the UDP guidebook5), the term ‘measure’ was used as a general concept for any factor (financial or nonfinancial) that enables or motivates a particular course of action or behavioural change to overcome a barrier. In the literature, the word ‘incentive’ is often used synonymously with ‘measure’.
- Grouping measures and design of the program. This step involved:
  - ✓ Applying a relatively broad set of complementary measures addressing barriers at various levels.
  - ✓ Measures were classified into two main groups: financial and non-financial measures, as it is of importance to policymakers which measures can be implemented by legal or other interventions, and which measures need to be financed (nationally or externally).

Energy Sector

2. Energy Sector

2.1 Preliminary Targets for Technology Transfer and Diffusion for Photovoltaics Solar (PV) and Wind Turbine Technologies.

Yemen is one of the world's most energy-insecure countries, with most of the country lacking access to sustainable energy. In general, the energy supply in Yemen has been limited and characterized due to the weak generation capacity, and high electricity losses from the inefficient grid. The top total generation capacity of the Yemeni electricity system before 2011 was about 1.223 GW and most of the electric energy supply has been dependent on fossil fuels including Mazut, Diesel, and Natural Gas. On the other hand, Renewable Energy (RE) share before 2011, was estimated at about 0.009% of the total energy mix, which increased significantly after 2015. The armed conflict that started in 2014 has tremendously impacted the electricity infrastructure and cut off the power supply to most of the population both in urban and rural areas (United Nations Development Programme (UNDP), 2021a).

The significant reduction in power generation capacities and further worsened electricity supply and services to unprecedented levels has led to severe impacts on health, education, water and sanitation, and the private sector, which heavily relies on functioning power supply. Consequently, access to centralized electric grids was completely suspended in several governorates. Thus, the use of Renewable Energy (RE) and solar PV technology particularly has gained importance as an alternative option to generating electricity and meeting individual needs and demands for self-consumption. Moreover, RE technologies have become quite important for increasing the supply of electricity, especially in isolated areas. The ongoing conflict showed that RE sources can play a greater role in addressing the energy shortage, given that Yemen has plenty of renewable resources, especially in the fields of solar energy and wind energy (Almohamadi, 2021).

In June 2009, the government approved the National Strategy for Renewable Energy and Energy Efficiency (NSREEE) which aimed to increase the RE share in the electricity mix and to decrease the total expenditure on diesel fuel.

Yemen has great potential for energy transition into clean energy depending on various RE resources, especially wind, and solar from theoretical and technical prospects as shown in *Table 2-1: Potentials of renewable energy resources in Yemen in MW.*

(United Nations Development Programme (UNDP), 2021b).

Table 2-1: Potentials of renewable energy resources in Yemen in MW.

Resource	Theoretical Potential (MW)	Technical Potential	
		Gross	Practicable
Wind	308,722	123,429	34,286
Geothermal	304,000	29,000	2,900
Solar Electric	2,446,000	1,426,000	18,600
Biomass-Landfills	10	8	6
Hydropower-Major Wadies	12-31	11-30	-
Solar Thermal-Solar Water Heater	3,014	278	278

According to NSREEE, the RE targets for grid electricity were divided into three different scenarios (Ministry of Energy and Electricity, 2009):

1) The high scenario projected a share of 20% renewables in the generation mix by 2025 (3,467 GWh);
2) The baseline scenario, which was publicly announced in official governmental events, targeted a 15% RE share in the power sector by 2025 (2,600 GWh);
3) The low market penetration scenario foresaw a share of 10% Renewable Energy (RE) in the generation mix by 2025 (1,733 GWh).

The off-grid targets for the respective scenarios were set as follows:

1) In the high scenario, 160,000 rural households (65% of the identified market potential) should be electrified with PV systems until 2025, with a total installed capacity of approximately 8 MW_p;
2) In the baseline scenario, 110,000 rural households (45% of the identified market potential) should be electrified with PV systems until 2025, with a total installed capacity of approximately 5.5 MWp; and
3) In the low market penetration scenario, 60,000 rural households (25% of the identified market potential) should be electrified with PV systems until 2025, with a total installed capacity of approximately 2.5 MWp.

Furthermore, NSREEE is intended to facilitate investments from the private sector to create a regulatory and special institutional arrangement for promoting RE, such as Electricity Sector Regulatory Board and a new authority Rural Electrification Authority. However, due to the ongoing civil war, these targets currently seem out of reach, and the strategy should be revised and updated, due to the implications of the war on infrastructure degradation, higher needs for energy for economic recovery and development, population growth, and the weakness of the institutional systems. In this regard, Yemen is currently working to increase its energy capacity by installing and diffusing RE into the energy mix, especially solar PV, and Wind turbines.

Simultaneously, the GOY is working on updating its, policies strategies, and plans to support the energy transition in the country, such as the NDC and Long-term Low Emission Strategy (LT-LEDs) which will give the energy sector priority and more attention to the investment from all the available resources due to its necessity in these critical moments for the country. From this perspective, the TNA project with its three phases receives more attention and interest from the government, due to its importance in prioritizing Yemen options which confirms the necessity of Solar PV and Wind turbines for the energy sector in addressing the lack of generation issues in Yemen, in line with climate action agendas and sustainable development goals. Besides, analysing the barriers and obstacles of diffusing such technologies has great paradigm shift potential in the increase of the RE in the national energy mix.
Accordingly, the target that Yemen seeks for the two technologies is as follows:

Table 2-2: Technologies and Preliminary target for prioritized technologies (Solar PV, Wind Turbine)

#	Prioritized technology	Sun-Technology	Preliminary target
1	Solar PV	Off- Grid Solar PV	The off-grid system has more potential than the on-grid due to the transmission system readiness that hinders its integration into the national grid. However, solar PV gains more attention through the of-grid systems, especially in rural areas, and some urban areas Including governmental facilities, such as schools, hospitals, etc. Therefore, the preliminary target is to be able to generate 250 MW of solar power by 2035 through off-grid PV systems.
		On-Grid Solar PV	Despite the challenges of the Solar PV system integration into the national grid, it still has a high potential to address the energy shortage in the country, increase energy generation in the country, and support the people to access sustainable energy resources. Thus, the target is to reach 150 MW through on-grid solar PV by 2035.
2	Wind Turbine	On and Off-Grid Wind Energy	Despite the potential of wind energy in Yemen, it has not been experienced practically, therefore, it is considered a new technology for the local Yemeni market. However, in the last 10 years, many studies and assessments were conducted and proposed plans for wind turbine farms installation in several locations around the country. Theoretically, Yemen can produce a high amount of energy from wind turbine technology, but for the coming six years, the preliminary target is to generate 200 MW through on and off-grid systems in suitable locations by 2035.

2.2 Barrier Analysis and Possible Enabling Measures for Off-grid and On-grid PV Systems

2.2.1 General Description of Off-grid and On-grid Solar PV technology

Yemen, known for being one of the regions with the highest solar radiation globally, is characterized by its arid and semi-arid climate, featuring towering inland mountains, desert highlands, and an extensive coastal semi-desert plain along the Arab Sea and the Red Sea. The country experiences warm and clear conditions, with generally high temperatures prevalent in its desert and coastal areas. The abundance of solar energy in Yemen is attributed to its geographical position within the solar belt, lying between the Tropic of Cancer and the Equator, as depicted in *Figure 2-1* (Al-Shetwi et al., 2021).

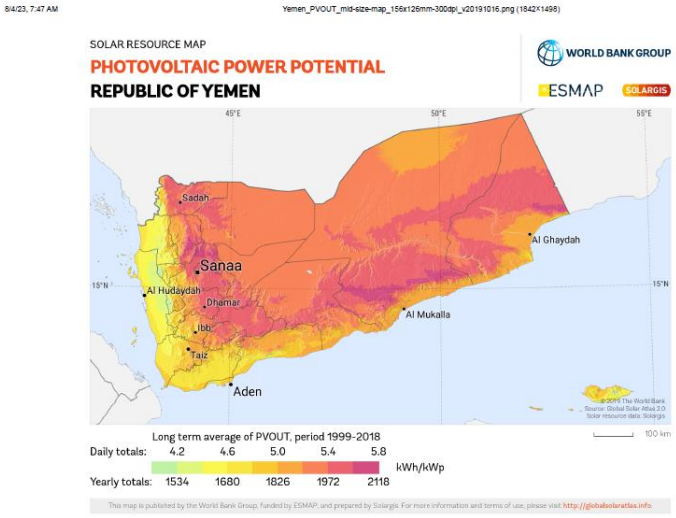


Figure 2-1: Solar photovoltaic (PV) map of Yemen (Al-Shetwi et al., 2021)

According to a recent paper by the Berlin-based Energy Access and Development Program (EADP), solar energy became the main source of energy for Yemeni households in 2016, two years after the start of its ongoing war. EADP said that 75% of the urban population and 50% of the rural population in Yemen have access to solar energy.

Since 2015, the amount of solar PV that has entered Yemen exceeded 1.5 GW, with the actual generation ranging from 400 to 600 MW as seen in *Figure 2-2* (Ersoy et al., 2022).The noticeable potential of RE has attracted some investments and donors to support this sector, and new large-scale projects in RE, and solar PV have started to be implemented in Yemen, with a capacity range starting from 15 to 120 MW for different purposes, including residential and agriculture. As an example, currently, a solar PV station with a capacity of 120 MW funded by the United Arab Emirates Government is being installed in Aden city and is expected to be connected to the national grid by 2024.

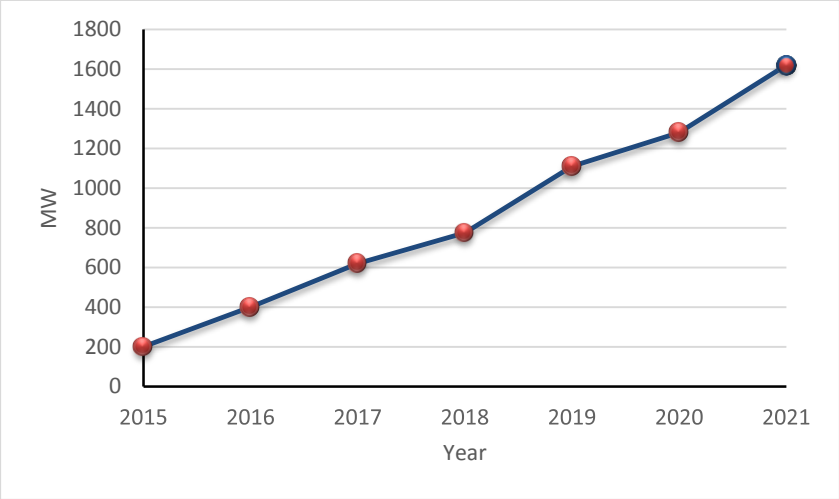


Figure 2-2: Expected installed solar PV system from 2015-2021 ***(Ersoy et al., 2022)***

Despite the high potential of solar PV in Yemen, there are some obstacles and barriers that should be overcome to widely spread this technology. The main challenges facing the transfer and diffusion of this technology are represented in the lack of funding necessary to establish small- and large-scale projects, and the absence of an enabling environment that can attract investments from all the available finance channels to promote the utilization of such technologies in small- and large-scale projects. Therefore, the GOY should develop innovative solutions to address these challenges, by facilitating the implementation of solar PV projects, on large and small scales, with a system that can be developed for residential in rural and urban areas purposes, and commercial processes, and agricultural and water supply services. In this regard, applicable systems that need to be promoted by the main actors in Yemen for solar PV deployment can be as follows:

- Off-grid system: isolated system, for all the above-mentioned purposes.
- On-grid system: connected to the national grid for residential purposes in urban areas

2.2.2 Identification of Barriers of Solar PV Technology (Off and On–Grid)

As already pointed out in Chapter 1, to identify barriers to this technology (on-grid and off-grid) in the energy sector, the following processes were used:

i) Reviewing relevant policy papers and other pertinent documents.
ii) Economic feasibility study.
iii) Workshop including stakeholders from the government, CSO, NGO, and private sector, *Figure 2-2*.
iv) Consultations with experts and stakeholders.
v) Problem tree (Annex 1-1).
vi) Solution tree (Annex 1-2).
vii) Market mapping tool (Annex 1-5).

As a result of the above process, the following main barriers were identified:

I. High initial system cost.
II. High interest rates on loans.
III. Inadequacy of subsidy programs.
IV. Scarcity of skilled labour to install and maintain the systems.
V. Existence of low-quality systems in the market.
VI. Gaps between existing legislation and actual implementation.
VII. Inadequate awareness of the benefits of solar technologies.
VIII. Absence of local manufacturers of PV systems.

IX. Old and inadequate strategies and plans.
X. Weak private sectors in the solar PV investment, especially the large-scale projects.
XI. Non-existence of an institutional body to coordinate the investment mobilization of the Solar PV systems.
XII. Inefficient and outdated grid system.

As barriers can be classified under several categories, it is found important to specify each barrier to better understand the problems. The table below *Table 2-3* shows the category of each barrier.

Table 2-3:The proposed barriers corresponding to the economic and financial category and non-financial category for solar PV technology (Off and on – Grid) technology.

#	Category	Sub-category	Barrier
1	Economic and Financial	Financial	▪ High initial system cost. ▪ High Interest Rates on loans ▪ Inadequate subsidy programs
2	Non-Financial	Legal and regulatory	▪ Existence of low-quality systems ▪ Gaps between existing legislation and actual implementation ▪ Old and inadequate strategies and plans
		Policymaker awareness and information	▪ Inadequate awareness of the benefits of solar technologies ▪ Lack of data and information
		Technical	▪ Absence of Local Manufacturers of solar PV systems ▪ Inefficient and traditional outdated grid system ▪ Weak technical capacity building and limited skilled labour to install and maintain the systems
		Institutional	▪ Non-existence of an institutional body to coordinate the investment mobilization of Solar PV systems and renewable energy in general. ▪ Weak private sector engagement in solar PV investment, especially large-scale projects

2.2.2.1 Economic and Financial Barriers of Solar PV technology (Off and on – Grid) technology.

I. High Initial System Cost

The initial system cost is a major impediment to the spread of solar energy technologies. For instance, in Yemen, the cost for the generation of 1 kw from solar PV ranges from USD 800 to 1400, which means, that for a 1 MW power plant, it can cost up to USD 1.4 million. This cost is very high compared to generating the same amount through conventional fuels, and diesel particularly, which ranges between USD 400k – 700k. Besides, the national economic fluctuations and inflation which affect the equipment costs, and make the technology unattractive to investors, especially on large-scale projects. In addition, the required solar energy incentives are not available, such as removing or reducing import duties, facilitating loans, reducing bank interest rates, and facilitating transactions.

II. High Interest Rates

High interest rates on loans are one of the main barriers to the deployment of solar PV systems. Countries that have lowered interest rates on loans for solar energy systems have been able to deploy this technology. Loan interest rates in Yemen range from 15% to 40%. This large percentage does not encourage investment, as solar PV energy projects require a large capital cost and a long loan period. Therefore, the economic viability of PV systems in Yemen will be strongly affected by the high-interest rate.

III. Inadequacy of Subsidy Programs

As a result of the national circumstances of Yemen due to the ongoing conflict, economic decline, and instability, the Yemeni government is unable to provide support for the establishment of such projects. Therefore, with their high initial cost, these technologies are not easily accessible to low-income people with limited subsidy programs.

2.2.2.2 Non-Financial Barriers of solar PV technology (Off and on – Grid) technology.

I. Weak Technical Capacity Building and Limited Skilled Labour to Install and Maintain the Systems

There are no comprehensive and continuous training programs in Yemen in the field of RE. However, there are some Yemeni universities, such as the University of Aden and the University of Sana'a, which teach some theoretical courses in solar energy and wind turbines, but they lack practical training. There are some non-governmental organizations and institutions that offer short and limited theoretical and practical training to qualify engineers and technicians in the field of solar energy. Thus, Yemen has a limited number of engineers and technicians trained to install, repair, and maintain solar-powered systems, especially on a large scale. The limited skilled manpower hinders the establishment, development, and maintenance of solar energy systems.

II. Existence of Low-Quality Systems

Yemen suffers from an influx of imported cheap and low-quality solar PV components, which undermines confidence in the technology. The main challenge is the application of standards due to the inadequacy of the legal and regulatory framework, as this influences the operation and lifespan of solar PV systems. The reason for the influx of these components is the lower prices which meet the economic situation of most of the population in the current national circumstances. Considering higher quality components will increase the initial cost of the system, which would be unreachable for the majority of the people in the country. However, maintaining the quality is crucial, because low-quality components are unreliable and break down or degrade in efficiency shortly after installation. This will in turn result in the prevailing of long-term problems in operation and maintenance. The reason for the availability of such components, mainly from China, is the lower prices considering good quality components will increase the initial system cost. Thus, regulations are required in this regard but not in a way that may increase capital system costs.

III. Gaps between Existing Legislation and Actual Implementation

Yemen Standardization, Metrology and Quality Control Organization is the sole responsible body for preparing and developing standards for importation. Recently, non-government laboratories in Aden (Aden Gulf Pearl Laboratories for Quality assurance) have been established for quality testing of electric and electronic devices and RE equipment. However, many solar energy devices and systems still enter the country without testing due to the lack of enforcement of the regulations. Besides, the absence of manuals and guidelines of solar PVs hinders the inspection process of the imported components. In addition, NSREEE from 2009, has not been implemented to date due to the political crisis being faced by Yemen since 2010.

IV. Inadequate awareness of the benefits of solar technologies and Lack of data and information

Most Yemenis, including policymakers and stakeholders, are not sufficiently aware of solar PV technology, especially for the large scale, as well as for the potential social, economic, and environmental benefits. The lack of awareness programs about the maturity and reliability of solar photovoltaic energy systems makes people reluctant to accept them. Moreover, most of them do not have a clear understanding of the real economic feasibility of the system considering the life cost analysis rather than looking just to the initial investment. Lack of awareness programs about the maturity and reliability of the systems still make people reluctant to buy new technologies. This inadequate awareness is mainly due to the lack of studies and research that show the economic, social, and environmental facilities of such systems.

V. Absence of local manufacturers of PV systems

There is no photovoltaic module manufacture in Yemen yet, not even assembling of modules. As a result, the cost of solar energy systems is high. The national production of solar PV systems can reduce its cost.

VI. Old and inadequate strategies and plans

The last strategy on RE was issued in 2009 and has not been implemented until now. All the work done in the field of RE was not oriented by the strategy due to the change in the national context after the war which is totally different from the release date of the strategy. Therefore, a new strategy must be developed, in-line with the new challenges

and demands on energy that are caused by population growth, and the high domestic migration from rural to urban areas.

VII. Weak private sector engagement in solar PV investment, especially large-scale projects

Due to the absence of national strategies, economic inflation, and institutional weakness, the private sector engagement in large-scale solar PV investment is very limited. Meanwhile, the private sector's involvement in small PV systems importation and installation is very active in the local market. Therefore, to attract the private sector in the large investment, more guarantees, and facilitation should be given by the government.

VIII. Non-existence of an institutional body to coordinate the investment mobilization of the solar PV systems

To date, Yemen does not have a national institutional body responsible for RE. Since there is no authority leading and coordinating the RE projects, the sector investment environment on such technology is not in the right direction. Moreover, this institutional gap was reflected in the development of a financial mechanism that is crucial to finance small and large-scale energy project investments.

IX. Inefficient and outdated grid system

The installation of solar PV on-grid system will require a smart grid system which is not available in Yemen. Moreover, the current grid is not ready to upload a new system besides the electricity generated through conventional power plants. The grid system is one of the biggest challenges that must be addressed because even if the solar PV system was installed, the efficiency would be very low, and the high generation would not make a huge difference in terms of energy supply for residential purposes in urban areas.

2.2.3 Identification of measures for solar PV technology

Barriers to Solar PV technology can be overcome through a combination of the following economic and financial measures, and non-financial measures. *Table 2-4* presents the proposed measures corresponding to the economic and financial barriers and *Table 2-5* presents the proposed measures corresponding to the non-financial barriers.

2.2.3.1 Economic and Financial Measures of solar PV technology

Table 2-4: The proposed measures corresponding to the economic and financial barriers and expected benefits of PV

#	Barriers	Proposed Measures	Expected benefits
1	High Initial System Cost	▪ To overcome the barriers of high installation costs, the government can address this issue by: o Reducing or exempting import duties on imports of this technology. o Encouraging the private sector to manufacture some components locally. o Facilitating access to other sources of financing provided by national banks and other global, multilateral funds. As an example, Yemen needs to integrate solar PV projects within its climate finance agendas, for adaptation and mitigation purposes. o Development of suitable financial mechanism and model to support the installation and implementation of RE and Solar PV projects	▪ Lower the overall cost of installation, making it more affordable. ▪ Create new local job opportunities and reduce dependence on imports. ▪ Increase the availability of funding for renewable energy projects, including solar PV projects in Yemen.
2	High-Interest Rates	▪ Facilitate access to concessional loans with reduced interest rates	▪ Enhance the finance mobilization for solar energy projects making it more

			affordable, and it will encourage investment in this technology which will lead to more deployment of solar PV Off- and On grids systems
3	Inadequacy of Subsidy Programs	▪ Identification of support programs and financial organizations and start negotiations with them to support solar energy projects. ▪ Establishment of a special fund for renewable energy and solar energy in particular	▪ Secure financial assistance and incentives for the development of solar projects. ▪ Provide dedicated funding for solar energy projects, making them more financially viable.

2.2.3.2 Non-Financial Measures of for solar PV technology

Table 2-5: The proposed non-financial measures corresponding to the non- financial barrier and expected benefits

#	Barriers	Proposed Measures	Expected benefits
1	Weak technical capacity building and limited skilled labours to install and maintain the systems	▪ Integration of Solar PV technologies within the programs of the engineering faculties in the universities, and technical institutions. ▪ Support the academic research on solar PV in Technical and engineering universities	▪ Enhance the educational curriculum and produce more skilled professionals in the field of solar energy. ▪ Contribute to technological advancements and innovation in the sector
2	Existence of Low-Quality Systems	▪ Development of quality and standards for the solar PV systems components ▪ Ensuring the enforcement of quality standards to avoid importing poor-quality systems. ▪ Development of manuals and guidelines for monitoring and testing the quality systems	▪ Ensure that only reliable and efficient products are imported and used, leading to better performance and longevity of solar PV systems. ▪ Protect consumers from poor-quality systems and increase confidence in the technology. ▪ Provide clear instructions for installation, maintenance, and troubleshooting, leading to improved system performance
3	Gaps between existing legislation and actual implementation	▪ Enforcing laws and legislation by competent authorities. ▪ Updating the legalization system to be in line with the country's needs and challenges.	▪ Create a favourable regulatory environment for solar energy projects and ensure compliance with industry standards and best practices. ▪ Address any gaps or inconsistencies in the legal framework, facilitating the development of solar energy projects
4	Low awareness of the Benefits of Solar Technologies and; ack of information	▪ Awareness-raising programs for society about the feasibility of solar technologies and their maturity ▪ Development of studies, assessments, and research that indicate the economic, social, and environmental potential and feasibility of such technology.	▪ Educate the public about the advantages and potential of solar energy, leading to increased acceptance and adoption. ▪ Provide evidence-based information to policymakers and investors, promoting informed decision-making
5	Absence of Local Manufacturers of PV Systems	▪ Support the establishment of local factories and workshops for manufacturing the PV systems locally.	▪ Create job opportunities, stimulate economic growth, and reduce dependence on imports.

		▪ Enhancement of regulatory and institutional framework that will enable the private sector and small entrepreneurs to invest in the local manufacturing of solar PV systems	▪ Foster domestic industry development and contribute to the growth of the renewable energy sector.
6	Old and Inadequate Strategies and Plans	The government should develop an updated renewable energy strategy that includes the following: ▪ Off- Grid Renewable energy plan to promote the installation and wide adoption of Solar PV systems. ▪ Plans for efficient integration of Solar PV into the national grids (On-grid Solar PV systems) such as the Action plans on the governorates level. ▪ Integrate the Solar PV systems (On and Off Grid) into the national climate plans and policies such as NDCs, LT-LEDs, and NAPs	▪ Provide a clear roadmap for the development and integration of solar energy into the national energy mix. ▪ Demonstrate the commitment to renewable energy and support the achievement of climate targets.
7	Weak Private Sectors in the Solar PV Investment, Especially the Large-Scale Projects	▪ Development and innovative incentives and institutional supporting laws to encourage the private sector in investment this technology.	▪ Attract private sector investment in solar PV technologies, particularly in large-scale projects. ▪ Unlock additional funding, expertise, and resources, accelerating the deployment of solar energy.
8	Non-existence of an institutional body to coordinate the investment mobilization of Solar PV systems and renewable energy in general	▪ Establishment of an independent institutional body responsible for RE investment coordination, and Solar PV systems particularly.	▪ Ensure efficient planning, resource allocation, and implementation of solar projects, leading to better coordination and optimized outcomes.
9	Inefficient and Traditional Outdated Grid System	▪ Conduct a technical assessment to evaluate the condition of the grid and its capability to integrate solar PV generation into the energy mix. ▪ Development of a plan to address the national grid issues based on the conducted assessment. ▪ Promote the utilization of smart grid systems for new Energy projects in the country and it should be within the county's national policies and plans	▪ Identify grid-related challenges and necessary upgrades for seamless integration. ▪ Guide infrastructure improvements, grid modernization, and grid-interactive policies, enabling higher penetration of solar PV and improving overall grid reliability and stability

2.2.4 General Description of Wind Turbine Technology

Yemen boasts an extensive coastline stretching over 2500 km along the Arab Sea and the Red Sea, averaging 45 km in width. The coastal regions here experience an average wind speed exceeding 8 meters per second annually, indicating significant potential for establishing wind farms, both along the coast and offshore. Yemen's geographical features, characterized by consistent and reasonably strong wind speeds, are conducive to efficient power generation. The country is also known for its distinct local wind patterns, including mountain valley and sea breeze winds. *Figure*

2-3 illustrates the wind energy density at 50 meters above ground level across Yemen. Notably, the mountain-valley regions, which are among the most densely populated areas in Yemen, host numerous small villages at altitudes of 1200 meters or lower. In these areas, wind turbines could be an economical solution for power generation. The wind is available virtually all year round, allowing wind turbines to generate electric power for household use in rural and urban areas in decentralized ways, through the following:

- Off-grid system: Isolated systems.
- On-grid system: Connected to the national grid.

The regions of Taiz, Aden, Lahj, Hodeidah's coastal plains, and Abyan are highly favourable for economic wind energy development. Each of these areas' records over 3500 full load hours annually, translating to an impressive installed capacity of more than 2,507 MW and an average annual electricity production of around 8,293 GWh. Taiz is especially suitable for setting up wind farms, thanks to its advantageous location that includes the coastal area of Al-Mokha and the nearby mountains in Arrous. Based on various studies and assessments by experts at the Ministry of Electricity and Energy (MEE), it is estimated that just 300 km² in Al-Mokha could potentially generate around 1.8 GW of energy (United Nations Development Programme (UNDP, 2021).

It's particularly noteworthy that most of these regions are endowed with both solar and wind resources, making them ideal candidates for wind-PV hybrid systems. The coastal areas experience high wind speeds for an extended period of six months, from September to March. This consistent wind pattern presents a promising opportunity to implement a hybrid system that combines wind farms with photovoltaic (PV) systems, diesel generation, or connections to the power grid.

However, despite its potential, several barriers and challenges should be addressed to promote its presence in the energy mix. Wind energy has its specificity compared to solar PV, especially in terms of installation and operation. For instance, the grid system to some extent can operate solar PV with a very low efficiency, but it cannot huddle any additional energy from wind turbines. Therefore, the projects of wind energy will be more applicable for isolated off-grid systems.

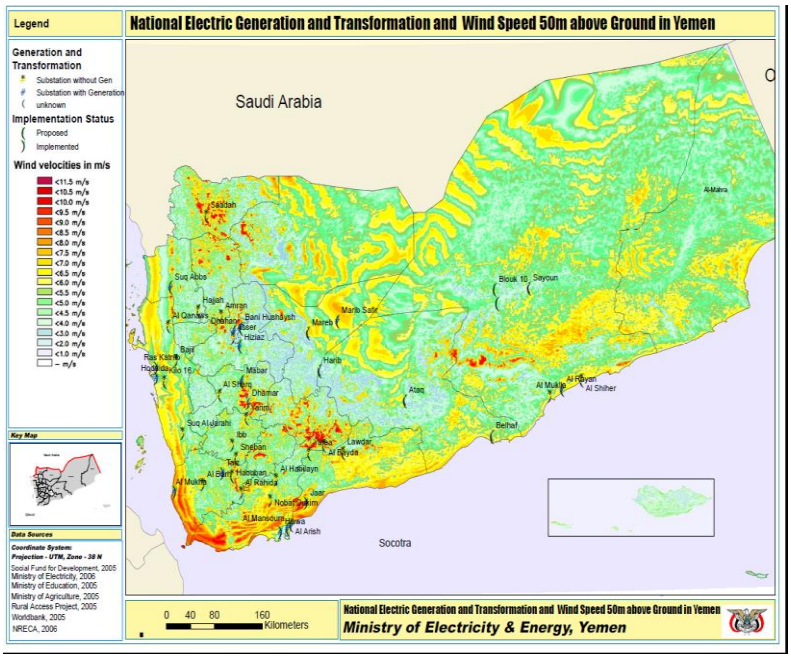


Figure 2-3: Wind speed map (50 m above ground level) (Al-Shetwi et al., 2021)

2.2.5 Identification of Barriers to Wind Turbine Technology

Categorization of Barriers for Wind Turbine Technology

Barriers of this technology may be categorized as:

(i) Economic and financial barriers.

(ii) Non-financial barriers, which could include:

- Capacity building.
- Technical, institutional, and policymakers' awareness.

Accordingly, the main barriers were identified as:

I. High initial system cost.
II. High interest rates on loans.
III. Inadequacy of subsidy programs.
IV. A Limited number of local skilled labour to install and maintain the systems.
V. Not available in the local market in commercial amounts.
VI. Inadequate awareness of the benefits of wind turbine technology.
VII. Absence of local manufacturers of small-scale systems.
VIII. Old and inadequate strategies and plans.
IX. Weak private sectors in the wind turbine technologies investment, especially large-scale projects.
X. Non-existence of an institutional body to coordinate the investment mobilization of the wind turbine systems.
XI. Inefficient and outdated traditional grid system.

Table 2-6: The proposed barriers corresponding to the economic and financial category and non-financial category for Wind Turbines (Off and on – Grid) technology.

#	Category	Sub-Category	Barrier
1	Economic and Financial	Economic and Financial	▪ High initial system cost
			▪ High interest on loans
			▪ Inadequate subsidy programs
2	Non-Financial	Legal and regulatory	▪ Old and inadequate strategies and plans
		Awareness and information	▪ Inadequate awareness of the benefits of wind turbine technologies and their economic, environmental, and social feasibility
		Technical and Capacity building	▪ Lack of data and information, especially the daily wind speeds
			▪ Absence of local manufacturers of small-scale systems
			▪ Almost no skilled labour to install and maintain the wind energy systems
			▪ Inefficient and outdated traditional grid system
		Institutional and private sector engagement	▪ Non-existence of an institutional body to coordinate the investment mobilization of wind turbine systems and renewable energy in general.
			▪ Weak coordination with the private sector to support the existence of the wind turbine in the market in a commercial amount as the PV systems, besides, the absence of national finance mechanisms and plans to motivate private sector investments in wind energy, especially large-scale projects

2.2.6 General Description of the Barriers for Wind Turbines

The barriers specified in *Table 2-5* are further categorized as: economic and financial and non-financial.

2.2.6.1 Economic and Financial Barriers of Wind Turbine Technology

The following section discusses the economic and financial barriers to the transfer and diffusion of wind turbine technology in Yemen:

I. **High Initial System Cost**

The prices of wind turbine technology have been reduced worldwide, but these prices are still considered high in Yemen because of fluctuations of the of the economy and economic inflation. Accordingly, the initial system cost of such technology becomes a major impediment to the diffusion of wind turbine technology and makes the technology unattractive to investors. In addition, the required wind turbine technology incentives are not available, such as removing or reducing import duties, facilitating loans, and reducing bank interest rates.

II. **High-Interest Rates on loan**

High-interest rates on loans are one of the main barriers to the deployment of wind energy systems. Countries that have lowered interest rates on loans for wind energy systems have been able to deploy this technology. Loan interest rates in Yemen range from 15% to 40%. This large percentage does not encourage investment, as wind energy projects require a large capital cost and a long loan period. Therefore, the economic viability of wind energy systems in Yemen will be strongly affected by the interest rate.

III. **Inadequacy of Subsidy Programs**

As a result of the current national circumstances, the Yemeni government will not be able to provide support for the establishment of such projects. So far, there is no external subsidy to establish such projects.

2.2.6.2 Non-Financial Barriers of Wind Turbine Technology

The following section discusses the non- financial barriers to the transfer and diffusion of wind turbine technology in Yemen:

I. **l Inadequate Awareness of the Benefits of Wind Turbine Technologies and its Economic, Environmental, and Social Feasibility**

The majority of Yemenis still have little information concerning the potential social, economic, and environmental benefits of wind turbine technology, including the policymakers. This low awareness is mainly due to the lack of high-quality studies, technical papers and research that produce a clear understanding of the feasibility of this technology, and their future socio-economic positive impacts. The lack of awareness may also just be the fact that information hasn't flowed to local communities.

II. **Old and Inadequate Strategies and Plans**

As mentioned earlier, the latest RE strategy was developed in 2009. Moreover, this strategy has not been implemented to date. The absence of the strategy minimizes the promotion of such technology in the local markets, even for off-grid systems.

Lack of Data and Information, Especially the Daily Wind Speeds

One of the issues facing Yemen in all aspects of climate change is the lack of daily and monthly data, such as wind speed, temperature, etc. This is considered one of the challenges when conducting any assessment of wind energy.

III. **Absence of Local Manufacturers of Small-Scale Systems**

Despite the simplicity of designing small systems wind turbines, there are no workshops for manufacturing or assembling processes for small-scale system components in Yemen.

IV. **Inefficient and Outdated Traditional Grid System**

The integration of wind energy into the energy mix in the national grid requires a smart grid, which is not available in Yemen. Besides, the current grid is outdated, which is unable to add any additional energy to the system.

V. **Almost no Skilled Labour to Install and Maintain the Wind Turbines**

Academic institutions in Yemen offer theoretical research and studies on wind turbines. However, practical training is so modest.

VI. **Non-Existence of an Institutional Body to Coordinate the Investment Mobilization of Wind Turbine Systems and Renewable Energy.**

Despite its potential, the non-existence of an independent RE authority affects the promotion of wind energy technology and utilization on large and small scales.

VII. **Weak Private Sector Engagement**

There is weak coordination with the private sector to spread this technology in the market. As a result, this technology is not available in the market in commercial amounts. Mainly, this barrier is linked to other economic and technical barriers, especially the cost of the technology which is currently very high compared to the local economy in Yemen.

2.2.7 Identification of Measures for Wind Turbine Technology

Barriers to wind turbine technology can be overcome through a combination of the following economic and financial measures and non-financial measures.

2.2.7.1 Economic and Financial Measures of Wind Turbine Technology

The proposed measures corresponding to the economic and financial barriers are shown in *Table 2-7*

Table 2-7: The proposed economic and financial measures corresponding to the non- financial barrier and expected benefits of Wind Turbine

#	Economic and Financial Barriers	Proposed Measures	Expected benefits
1	High Initial System Cost	▪ Most of the components of wind turbines are imported from outside the country. Thus, the high initial cost can be reduced by o Reducing or exempting import duties on imports of this technology. o Encouraging g Energy Sector Companies (ESCOs) to import technology by facilitating access to loans with reduced interest rates. o Development of financial mechanism and model to finance the technology adoption on large and small scale	▪ Enhancing the affordability and feasibility of wind energy installations Job creation and economic growth in the country. ▪ Reducing dependence on imports. ▪ Creating a sustainable financing framework for wind energy projects. ▪ Unlocking capital for large-scale and small-scale wind energy initiatives. ▪ Increasing accessibility to financing, enabling ESCOs to invest in wind energy projects. ▪ Stimulating the growth of the wind energy sector and attracting private investments. ▪ Facilitating the adoption of wind energy technology and accelerating the transition to renewable energy sources.
2	High-Interest Rates on loans	▪ Reduce the interest rates, and provide concessional loans for such technologies	▪ Lowering the financial burden on wind energy project developers. ▪ Encouraging investment in wind energy infrastructure. ▪ Increasing the competitiveness of wind energy compared to conventional energy sources.
3	Inadequacy of subsidy programs	▪ Provide subsidies by identifying and accessing various subsidy programs such as international organizations concerned with the environment and climate change, as well as other parties that have such initiatives.	▪ Offsetting the high costs of wind energy projects. ▪ Promoting the adoption of clean and sustainable energy solutions. ▪ Supporting the achievement of environmental and climate change goals.

2.2.7.2 Non-Financial Measures of Wind Turbine Technology

The proposed measures corresponding to the non-financial barriers are given in *Table 2-8*.

Table 2-8: The proposed non-financial measures corresponding to the non- financial barrier and expected benefits

#	Economic and Financial Barriers	Proposed Measures	Expected benefits
1	Old and Inadequate Strategies and Plans	▪ Develop new strategies and policies that fit with the national circumstances of the country after seven years of armed conflict. In the new strategies, wind energy must be given priority for implementation and investment alongside Solar PV as the two most potential renewable energy resources. ▪ Integrate the wind turbine technology within the national climate change policies for mitigation and adaptation purposes, such as NDC, NAP, and LT-LEDs	▪ Diversifying the energy mix and reducing reliance on fossil fuels. ▪ Expanding renewable energy generation capacity. ▪ Contributing to the reduction of greenhouse gas emissions and mitigating climate change.
2	Low awareness of the Benefits of Wind Turbine Technologies and its Economic, Environmental, and Social Feasibility	▪ Support the field of research and studies on wind energy, in addition to holding workshops, issuing advertising flyers, paying attention to capacity-building initiatives, etc. ▪ Conduct economic feasibility studies and they must be produced to assess the economic, environmental, and social potential impacts of wind energy technologies.	▪ Offsetting the high costs of wind energy projects. ▪ Promoting the adoption of clean and sustainable energy solutions. ▪ Supporting the achievement of environmental and climate change goals.
3	Lack of Data and Information, Especially the Daily Wind Speeds	▪ Establish meteorological stations to record the daily wind energy, especially in the high potential locations.	▪ Gathering accurate data for wind resource assessment. ▪ Identifying optimal sites for wind energy installations. ▪ Improving the efficiency and performance of wind energy systems.
4	Absence of Local Manufacturers of Small-Scale Systems	▪ Support the local communities and NGOs to establish workshops to design small-scale wind turbines, to be used out of the grid, and for residential purposes.	▪ Empowering local communities and NGOs to participate in renewable energy generation. ▪ Promoting energy self-sufficiency at the community level. ▪ Fostering innovation and technological development in the field of wind energy.
5	Almost no Skilled Labor to Install and Maintain the Systems	▪ Launch training Programs for wind energy installation and operation. Besides, integrate wind energy into the programs of technical institutions, and engineering universities.	▪ Building a skilled workforce for the wind energy industry. ▪ Ensuring the proper installation, maintenance, and operation of wind energy systems. ▪ Enhancing job opportunities and creating employment in the renewable energy sector.
6	Inefficient and Outdated Traditional Grid System	▪ Support the installation of off-grid wind energy systems for the local communities in suitable areas.	▪ Providing access to electricity in remote and underserved areas.

		▪ Upgrade the national grid system, and promote the idea of a smart grid system, by prioritizing it within the investment plans and strategies of energy efficiency.	▪ Improving energy security and resilience in off-grid locations. ▪ Empowering local communities to meet their energy needs sustainably. ▪ Enhancing the integration of wind energy into the existing power infrastructure. ▪ Enabling efficient transmission and distribution of wind-generated electricity. ▪ Facilitating grid stability and accommodating higher shares of renewable energy.
7	Non-Existence of an Institutional Body to Coordinate the Investment Mobilization of the Wind Turbine Systems.	▪ Establishment of an institutional body responsible for Re investment coordination, and identify wind turbines within the top priorities for investment	▪ Streamlining investment processes and eliminating bottlenecks. ▪ Ensuring efficient allocation of resources to wind energy projects. ▪ Promoting transparency and accountability in the wind energy sector.
8	Weak Coordination with the Private Sector.	▪ Incentives and institutional supporting laws to encourage the private sector in this technology.	▪ Encouraging private sector participation in wind energy development. ▪ Fostering innovation, competition, and technological advancements. ▪ Leveraging private sector expertise and resources for the growth of the wind energy industry.

2.3 Linkages of Identified Barriers for Solar PV and Wind Turbine Technologies.

As seen above, since both technologies are under RE, there are linkages between the barriers of solar PV and wind turbine deployment. Besides, it can be noticed that all the barriers, both financial and non-financial are interlinked with one another. As an example, institutional and technical weaknesses play an important role in the prices of the system and can motivate the banks to provide a subsidy program for such technologies. For this reason, the interlinked barriers and obstacles between Solar energy and wind energy can be summarized as follows:

I. Economic and Financial

A major hurdle in advancing any solar PV or wind project, particularly in the current scenario, is the financial challenge. Adequate funding, which is hard to come by in the present circumstances, is crucial for a project's success. As a Least Developed Country (LDC), Yemen highly needs financial support through climate finance initiatives, international aid grants, or concessional loans from organizations dedicated to large-scale infrastructure projects. It's a known fact that the initial costs of solar PV and wind energy systems are higher compared to traditional fossil-fuel systems. This disparity makes it challenging for cash-strapped rural households to secure loans, especially for small-scale PV systems. Furthermore, the lack of accessible credit options and high-interest rates on such credits pose significant barriers to the development of solar PV and wind energy. An additional challenge is the absence of effective coordination between local communities and the central government regarding the planning and financing of solar and wind energy projects.

II. Technical

A significant technical challenge in the development of solar PV and wind energy in Yemen is the absence of essential infrastructure needed to support these technologies. Moreover, there's a scarcity of professionals trained in the setup, maintenance, demonstration, and operation of RE systems. This gap raises concerns about the reliability of these technologies, leading to hesitancy in importing and installing RE solutions. Additionally, the country faces a shortfall

in the physical infrastructure of transmission and distribution networks, along with the necessary services and equipment required by a national electrical company.

Another issue is the inadequate management and maintenance of equipment, which, along with the low technological reliability, diminishes consumer trust in certain RE technologies, thereby impeding their widespread adoption. This situation is exacerbated by the fact that much of the solar PV and wind turbine equipment is imported from more developed countries to nations like Yemen, leading to a lack of readily available spare parts and the requisite skills for servicing and repairing the equipment. This deficiency often results in equipment failure, which, in turn, disrupts the energy supply.

Additionally, from the perspective of investors, the lack of adequate procedures, standards, and guidelines concerning the reliability, durability, and efficiency of RE systems poses a significant barrier to the commercialization of large-scale Solar PV and wind energy projects. Another critical technological challenge in the RE sector is energy storage. Despite the abundant availability of wind and solar power, their supply is not constant, and power grids require a balance between demand and supply to function effectively. Addressing this issue necessitates the construction of large batteries capable of compensating during periods when renewable resources are unavailable. However, there are concerns regarding the cost, periodic maintenance, rapid discharge rate, capacity, and lifespan of these batteries, which need to be addressed to enhance the efficiency of solar PV systems and wind turbines.

III. Regulations, Policies, and Strategies

The absence of solar PV and wind turbine technologies, along with a lack of national RE policies, plans, and regulations, administrative challenges, unrealistic governmental objectives, and insufficient incentives, could hinder the rapid expansion of these technologies in Yemen's power sector. A notable example is the absence of a grid code in Yemen, which is essential for regulating and coordinating the activities of electricity operators, producers, distributors, and consumers. This gap in proper economic incentives results in elevated costs, adversely affecting the future growth of Renewable Energy (RE).

Furthermore, the Yemeni government has not yet implemented a tax policy specific to RE. It is crucial for the government to introduce tax incentives for purchasing RE equipment and to grant tax exemptions for services using renewable sources. Such a policy would attract potential investors and industry stakeholders to invest in RE. Additionally, standards and certifications should be established to ensure that equipment and parts imported or procured from abroad comply with the importing country's standards. These certifications are important to ensure that the products are imported and operated in accordance with local laws. The absence of such standards and certifications leads to confusion among energy producers and creates unnecessary challenges. Moreover, the RE Strategy is outdated today, and a new strategy should be developed with a new target for RE contribution to the energy mix, especially for solar PV and wind energy as the most tow potential RE options.

IV. Institutional

The primary reason for the limited spread of any technology is the lack of effective institutions. In Yemen, the absence of an institutional framework or a functional mechanism specifically for the RE sector leads to a significant gap in information availability for both consumers and producers. Additionally, the lack of a Research and Development (R&D) culture, combined with insufficient involvement of stakeholders, can complicate the adoption of technology and result in poorly prioritized decision-making. Lastly, the absence of professional institutions and laboratories constitutes another significant institutional obstacle.

V. Social and Awareness

Several factors contribute to public resistance towards shifting from traditional energy sources to renewable ones, such as a lack of awareness and knowledge about the advantages of Solar PV and wind energy. For example, in Yemen, many people in rural areas are not educated about these technologies, leading to a general lack of awareness. Additionally, there is a widespread lack of public understanding regarding the everyday life benefits of these technologies and an underappreciation of the social and environmental impacts of traditional energy sources. Another contributing factor is the perceived high cost of installing RE systems. To address these issues, raising community awareness and focusing on socio-cultural practices are essential. Furthermore, there is a noticeable absence of encouragement or inclination among specialists and higher societal levels to opt for renewable generators like solar

PV systems over traditional diesel generators. Finally, the absence of a robust local skilled labour force capable of building, designing, operating, and maintaining solar PV systems and wind farms presents another social challenge.

2.4 Enabling Framework for Overcoming the Barriers to Energy Technologies.

As the technologies are under RE, their barriers and obstacles are almost similar. Therefore, to find an enabling environment and framework to diffuse these technologies into implementation, several actions must be taken into consideration as presented in Table 2-9.

Table 2-9: Enabling framework for overcoming barriers for both PV and Wind Turbine in energy sector, also the responsible government authority.

#	Enabling Environment	Measures Needed	Responsible Government Authority
1	Old and inadequate strategies and plans	▪ Develop an updated RE strategy, and ensure it covers energy security and economic, environmental, and social benefits. Moreover, the strategy set targets for the percentage of wind and solar PV in the energy mix, the percentage of GHG mitigations, and pollution reduction.	▪ Ministry of Electricity and Energy ▪ General Authority for Investment
2	Non-existence of an institutional body to coordinate the investment mobilization of solar PV and wind turbine systems.	▪ Establish an independent institutional body for RE to lead and coordinate the promotion of RE into the implementation presence in the market, particularly solar PV and wind as the most two potential options. Moreover, this body will be responsible for developing the strategies, policies, and plans and monitoring and orienting ensuring their implementation.	▪ Ministry of Electricity and Energy ▪ General Authority for Investment
3	High initial system cost and high-interest rates on loans.	▪ The GOY must create an encouraging investment climate to attract domestic and foreign investment to this sector by providing more investment facilities and incentives. ▪ Besides developing innovative finance and investment plans to overcome the high capital costs of these technologies. ▪ For instance, these two technologies must be prioritized for the climate finance projects, in the national documents, such as NDC, LT-LEDs, and NAPs. ▪ Moreover, the GOY must utilize the chances of the carbon market to finance the solar PV and wind energy projects by (1) joining the available carbon market platforms and enhancing its preparedness and readiness to engage in the coming carbon market under Article 6 of Paris Agreement, and (2) ensuring that the designed projects are aligned with carbon market criteria and requirements.	▪ Ministry of Finance ▪ General Authority for Investment
4	Weak private sectors in the RE technologies investment, especially the large-scale projects	▪ Develop plans and policies for private sector engagement in investing in such technologies. ▪ The government is encouraged to reduce the high cost of RE systems by offering a new policy of taxes concerning RE technology, subsiding the dependency on conventional energy, and providing more attention to rural and desert communities for the use of RE. In addition, clear	▪ Ministry of Finance ▪ General Authority for Investment

		regulations and legalization for RE and solar PV and wind turbines particularly. ▪ Encourage the private sector to establish factories for renewable energy technologies components.	
5	Low awareness	▪ Integrate RE into the universities and technical institutions' curriculums. ▪ Spreading awareness in society about renewable energy through symposiums, workshops, and by activating the media to explain the advantages of renewable energy. ▪ Raising awareness among students on RE topics through educating, at various educational levels, their concepts and benefits for the environment, energy security, and the economy. ▪ Enhancing the culture of R&D through expanding research and higher education institutes and technology centres, to avoid the low awareness of the benefits of the two technologies.	▪ The Ministry of Education and Ministry of Information
6	Lack and absence of skilled labours	▪ Educational programs for renewable energy should be provided at the bachelor's level and in vocational training institutions, including solar energy and wind energy, ▪ The engineers and technicians must receive adequate hands-on training such as the installation, maintenance and operation of systems. ▪ Launch programs to train the youth and entrepreneurs to domestically manufacture wind and solar components and establish workshops for these purposes.	▪ Ministry of Electricity and Energy, ▪ Ministry of Higher Education and Vocational Training
7	Inadequate subsidy programs	▪ Communicating with different supporting organizations to get aid for RE projects	▪ Ministry of Electricity and Energy ▪ Ministry of Planning and International Cooperation

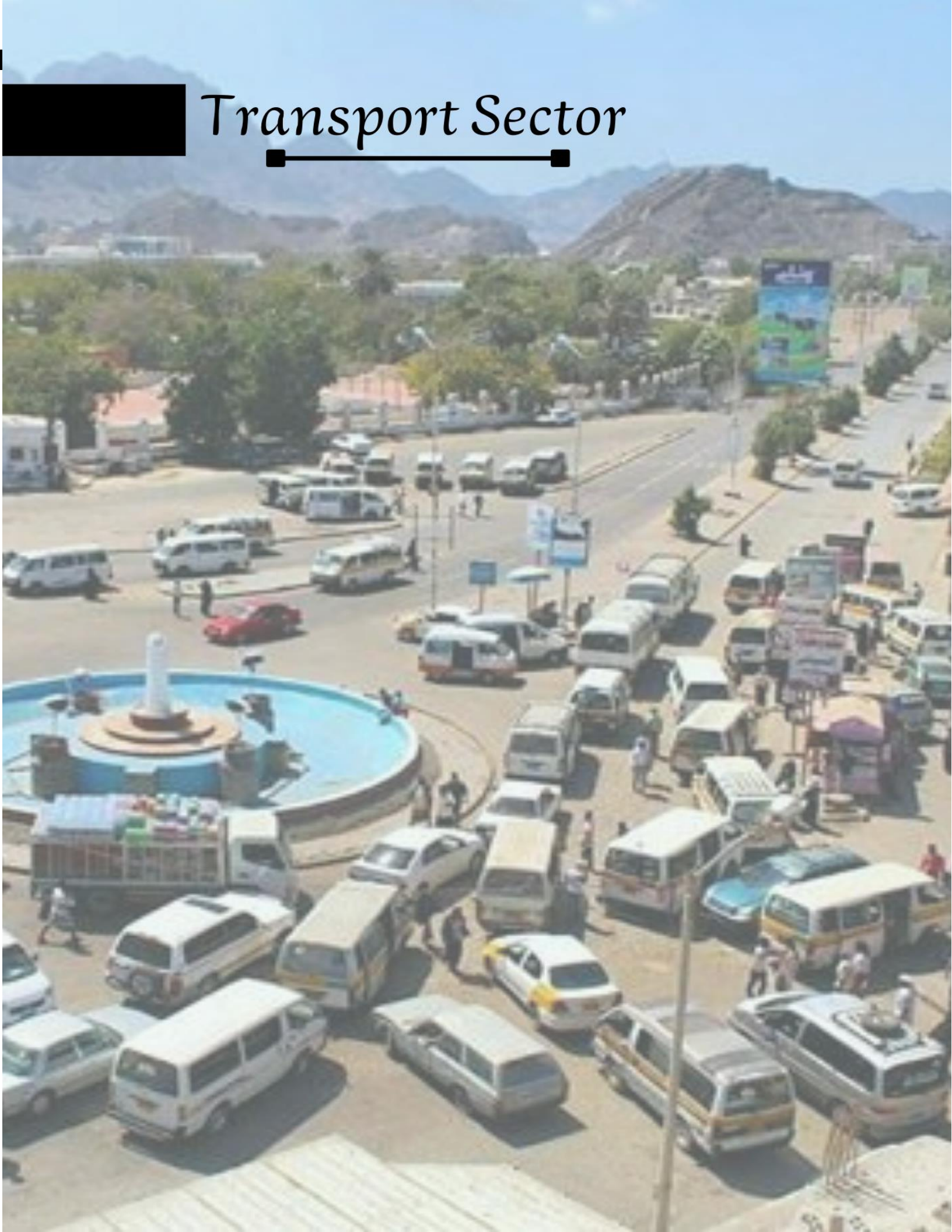
Expected outcome and overall impacts:

The implementation of solar PV and wind turbines represents a significant leap forward in the global effort to transition towards renewable energy sources. At the local level, the adoption of solar PV and wind turbines can contribute to the global transition towards renewable energy, while reaping the benefits of clean, affordable, and sustainable power generation. The expected outcome and overall impacts can be as the following:

- Increased Renewable Energy Deployment: Widespread adoption of Off and On-grid renewable energy systems contributing to the overall energy mix in Yemen.
- Enhanced Energy Accessibility: Improved access to sustainable energy for local communities, positively impacting health, education, and economic activities.
- Strengthened National Capacities: Strengthened technical and institutional capacities at the Ministry of Energy and Electricity (MEE) and among stakeholders.
- Job Creation and Economic Development: Establishment of renewable energy projects contributing to job creation and economic development.
- Environmental Benefits: Reduced dependence on fossil fuels, leading to a decrease in greenhouse gas emissions and environmental degradation.
- Knowledge Transfer and Public Awareness: Increased awareness and knowledge about the benefits of renewable energy, fostering a culture of sustainability.

- Paving the Way for Future Expansion: The successful implementation of this project can serve as a model for future expansions and investments in renewable energy initiatives in Yemen.

Transport Sector



3. The Transport Sector

3.1 Preliminary Targets for Technology Transfer and Diffusion of the Bus Rapid Transit (BRT) & the Hybrid Electric Vehicle (HEV) technologies

The transportation system in Yemen is old, inefficient, mismanaged, and undeveloped. All these drawbacks are coupled with weak or no enforcement of legislation and by-laws that regulate the transport sector in the country. The past government development plans had made some progress in developing roads in the remote areas of the country. Most of the funding has been from regional and international donors. The major cities have witnessed some improvements in road construction and repairs. But, due to weak management, a lack of vision for future infrastructure for a network of roads, that can absorb the increasing numbers of vehicles on the roads, has led to congested roads. The plans for the transportation sector didn't cover most of the actual needs and demands to develop a modern transport system, particularly for public mass transport such as the BRT. Road infrastructure has suffered greatly from the recent conflict, and with the absence of road repairs, many passengers' vehicles face difficulty in getting to their destinations on time.

Pollution caused by transport, alongside energy, constitutes the major sector contributing to GHG emissions due to high fuel consumption. In 2010, the total number of vehicles on the road was estimated to be 872702 vehicles. Private cars take the largest share of the total with 46.83%, while buses have the lowest share of 4.35%, and it is expected that this rate has doubled since 2020. Passenger road transportation accounts for 65.31% of the number of vehicles, while road freight transportation accounts for the remaining 34.69 %. In energy related GHG emissions in 2010, in term of consumption activity, emissions from transport showed the highest share of GHGs emissions of about 33%. In 2010, the total energy consumed by the transport sector was estimated to be 187 GJ (Sufian Towfick & Asaad Abdulraqib, 2015).

Previous actions, plans, and efforts by the authorities to reduce GHGs emissions in the transport sector were carried out but were very limited. These were addressed to all stakeholders, the government, the authorities concerned, car-suppliers and the relevant private sectors and can be summarized as follows:

i- Reduce taxation on new gasoline vehicles which have emission reduction equipment fitted into them. The reduction/omission should also apply to any vehicles imported which run on renewable technologies.
ii- Introduce a yearly vehicle test that includes emission levels so that inefficient old cars, buses, and lorries can gradually be phased out.
iii- Raise taxations on new imported diesel vehicles.
iv- Continue the existing ban on importing vehicles of 5 years old and above.
v- Introduce standards and norms for all imported used vehicles.
vi- introduce gasoline instead of diesel fuel for Lorries & buses.
vii- introduce efficiency standards for vehicle exhausts and limit the operation of old vehicles.

All these proposed options and solutions were faced with many challenges, especially due to the weak legislation and the old plans and strategies. Some of these barriers can be summarized as:

1- No or weak cooperation, coordination, or communication, between stakeholder/car suppliers and between relevant government institutions.
2- Lack of enforcement of by-laws, legislations, regulations.
3- No effective governance, aggravated by political instability.
4- No or weak government & public awareness on the importance of GHGs mitigation & the importance of introducing new technologies in all development sectors including road transport.
5- Weak trade policies to encourage & enhance imports of vehicles that have less no less or no GHG emissions, and run on RE, such as hybrid vehicles.

However, the government and the relevant authorities are planning new technology options that can be introduced in the transport sector to limit the number of vehicles on the road and reduce the consumption of fossil fuels. These technology options will contribute greatly to the reduction of GHG emissions by the transport sector and reduce the number of passenger vehicles on the roads. The two technology options already prioritized are - the *introduction of Bus Rapid Transit (BRT)* and *the promotion of the Hybrid Electrical Vehicle (HEV),* which could face various barriers and challenges. Therefore, steps should be taken to overcome these barriers and challenges, which can contribute to the diffusion of these technology options into implementation in the country.

Public mass transport such as BRT, can play an important factor in the transformation of transport in the country into more modern, efficient, fast transport. An advantage can be added, is that if BRT system buses are operated by gas-fuel, and subsequently end up with electrical buses in the future.

Table 3-1: Technologies and Preliminary target for prioritized technologies (Bus Rapid Transit system (BRT), Hybrid Electric Vehicle (HEV))

#	Prioritized technology	Preliminary target
1	Bus Rapid Transit system (BRT)	The introduction of the gas-fuelled and electrical BRT system can reduce the travel fare and will be perceived by most of the daily city travellers with positive altitudes, and joy, that finally they can use a modern transport with all its benefits. Many daily commuters such as school children, college students, shoppers, civil servants, traders, and workers will prefer using BRT. This technology – BRT can be implemented in all major cities throughout the country, it is expected to cover most of the major cities in the country by 2040. The target is to start the implementation of at least two systems in two cities by 2035
2	Hybrid Electric Vehicle (HEV)	The Hybrid Electric Vehicle HEV needs an efficient promotion procedure for it to spread on a wide scale in the country. This technology option is suitable for the country and can contribute to the reduction of GHG emissions in major cities. Low-income individuals will prefer to use the HEV, and the HEV acquisition can spread throughout the country, particularly in the country's rural areas. The period for the promotion of HEV can be within a year, once the necessary and required procedures are implemented. Thus, the target for the HEV deployment is to reach 30% of the HEV sold by the car companies in Yemen by 2030.

3.2 Barrier Analysis and Possible Enabling Measures

The method of identifying barriers and solutions (measures/incentives), consists of several actions and procedures. The first step will be to contact the relevant institutions from government and private stakeholders to establish coordination with sectoral working groups. These actions are to form a technology-specific working group, one for the introduction of BRT technology, and the other for the HEV promotion. These working groups can be from the ministries of transport, trade, treasury, and public works (i.e., road construction and maintenance). Also, the customs authority, government-owned public corporations for transport, and other private stakeholders such as travel and tourist companies particularly those using bus transport, car and spare-parts suppliers.

First step, sectoral working groups were established for the coordination between the relevant government institutions and the private stakeholders, the purpose was to form a technology-specific working group for both the introduction of BRT and the promotion of HEV. Then the second step, consisted of a broad screening of barriers, through the broad review desk study, of policy papers, regulations, consultant reports, and industry reports, to find out what had already existed in the country that represented challenges and barriers to the transfer and diffusion of each technology. These was supplemented by additional interviews, bilateral meetings, and stakeholder consultations, to obtain deeper insights and understanding of each technology. The third step, after the processes of consultations with various stakeholders, written feedback, and bilateral communication, a barrier analysis for the barriers and challenges for each technology option was carried out. The fourth step, all the identified barriers were listed, prioritized, and ranked in the order of

the crucial, important, and tailing by the less important and unimportant. This was done in a workshop with all the relevant participants from all relevant government and private sector stakeholders.

The solutions and measures to overcome the challenges and barriers were thought of during the discussions in the workshop for the identification of barriers. The Market Mapping approach was used, also, the Problem Tree approach that was used for the identification of the barriers, was also used for the identification of solutions and measures in a Solution Tree approach to overcome these barriers.

3.2.1 General Description of the Bus Rapid Transit (BRT) Technology

The BRT system is a high-capacity transport system with dedicated lanes for bus transit. It consists of a systematic combination of infrastructure (bus ways, stations, terminals) with organized operations and intelligent technologies to provide a higher quality experience than possible with traditional bus operations. Main services enhancements are increasing the average speed and ensuring matching of the scheduled timetables.

Currently, there is no public bus transport (governmental or private companies) within major cities in the country. However, establishing a mass public bus transport will entail a large investment in the infrastructure, which includes bus stations, bus stops, bus lanes, maintenance garages, electronic surveillance of buses, and other necessary measures. There are other procedures, such as the need for political decisions, legal issues, social issues, trade legislation & by-laws, local people consensus, environmental issues, and gender issues to be considered. It must be emphasized that introducing public bus transport in major cities will solve many problems. It will reduce road congestion greatly, cut down CO_2 emissions, and provide safe, comfortable, time-saving, and affordable travel for most if not all inner-city passengers. Moreover, the options of the natural gas and electrical buses will be studied and analysed based on their feasibility and applicability in the country.

The advantages of the BRT are the reduction of congestion, energy consumption, CO_2 emissions, increased road capacity, and efficient transportation facilities. However, it is expected that this technology may face some challenges due to the current infrastructure, which will be taken into consideration in the analysis.

3.2.2 Identification of Barriers for the Introduction of Bus Rapid Transit (BRT) Technology

The consultants followed the BA&EF process to identify the barriers during the first desk study mentioned in *chapter 1* to gather the previous governmental reports, regulations, by-laws, legislations, and policies on the transportation sector, to draw out an initial view of the status of the transport system in Yemen, and to find out obstacles and challenges. forward a workshop designated for that purpose through in-depth discussions between the transport consultants and the relevant stakeholders (government and private sectors), the barriers are characterized and identified in specific categories accordingly. The barriers for the BRT were categorized accordingly into financial and economic barriers, and non-financial and non-economic barriers, as shown in the table below:

Table 3-2: The proposed barriers corresponding to the economic and financial and non-financial category for Bus Rapid Transit (BRT).

#	Category	Sub-Category	Barriers
1	Financial and Economic	▪ Financial and Economic	▪ Lack of financial donors for such a project
			▪ High investment cost of BRT project
			▪ High inflation rate, inadequate financial policies The high inflation rate means that the value of local currency is not stable, prices of goods, and the cost of fuel and services continue to increase. The major reason is the current turmoil in the country, another reason is the absence of new proper financial policies to deal with the continuous change in the

			financial market. These challenges act as obstacles for investment or donors for the BRT project
			▪ Increase the unemployment rate. where introducing the BRT has adverse impact on (small bus owners), also on the tax that the transport sector gets from the drivers.
2	Non-Financial	▪ Legal and Regulatory	▪ Insufficient legal and regulatory framework for the transport sector especially public transport.
		▪ Communication and Coordination between the actors and stakeholders in the relevant sectors	▪ No coordination between the stakeholders, in the same sector or with other sectors. There is a lack of coordination and collaboration between government transport authorities and local road travel companies, which can help in introducing new transport technologies such as BRT. Moreover, different transport authorities have different objectives, also, the same goes for the private transport sector, companies tend to compete without regard to the public interest, some of it due to the political instability
		▪ Institutional, Organizational and Human Skills	▪ Limited institutional and organizational capacity.
			▪ Lack of qualified personnel to manage, regulate, monitor, evaluate, and organize, and carry out the required procedures for the introduction and operation of BRT.
			▪ The regular decision-making process for implementing BRT can be expected to be more bureaucratic and might cause delays and cost overrun
			▪ There is no national strategy plan on the technology or the sector itself
		▪ Social, and Cultural Behaviour	▪ Most people may be hesitant to use new technology such as BRT due to the waiting time where most people prefer using small buses that wait a few minutes to move
		▪ Information and Awareness	▪ Lack of information on the BRT in the scope of the country stakeholders, labourers, drivers, and local people in this sector
		▪ Technical	▪ No standards, codes, and certifications of new technology vehicles.
			▪ There are no specialized personnel for the service and maintenance of BRT.
		▪ Infrastructure	▪ Poor infrastructure for the BRT system as the current infrastructure needs to be repaired or a new one established, considering the random urban expansion that happening recently

3.2.2.1 Financial and Economic Barriers

The Bus Rapid Transit (BRT) project requires large investment, which may delay or avert the international donors from financing such a project and there is no interest of the donor for such a project. Also, the current high inflation and inadequate financial

policies may not attract and encourage the private sector in such projects. All of the above barriers act as obstacles to the introduction of the BRT project. The adverse impact on the owners of small buses' daily income, since the BRT may reduce the number of passengers that use small buses, must be considered.

3.2.2.2 Non-Financial Barriers

I. Insufficient legal and regulatory framework for the transport sector especially public transport.

Legislations & by-laws that regulate the transport system almost don't exist or are not implemented because of the current political conflict, where the current types of transport are not public transport but rather semi-public transport which operated by low-income individuals who are mostly young and couldn't find jobs in either government or private firms' jobs.

II. Communication and Coordination between the Stakeholders and Actors in the Relevant Sectors

Weak or no effective coordination between relevant government institutions regarding the improvement of transportation within cities and between governorates. Also, the absence of collaboration between government transport authorities and local road travel companies hampers the adoption of new transport technologies like BRT. Furthermore, varying objectives among different transport authorities and within the transport sector lead to competitive practices that often neglect public interests, exacerbated in part by political instability.

III. Institutional, Organizational and Human Skills

The institutional capability and organization potential in the transportation system are very weak and almost non-existent, where the current transport system is semi-public transport that is managed by low-income men. Additionally, the lack of qualified personnel poses significant challenges to the smooth functioning of the Bus Rapid Transit (BRT) system. Without capable individuals to oversee and manage various aspects of the BRT, such as regulation, monitoring, evaluation, and organization, the system's effectiveness and efficiency may be compromised.

The conventional decision-making process involved in implementing BRT systems often involves multiple layers of bureaucracy, which can slow down progress and hinder timely execution. Decision-making may require approvals from various government departments, transportation agencies, and local authorities, adding complexity and potential bottlenecks to the process. As a result, project timelines can be extended, leading to delays in the overall implementation of the BRT system.

Currently, there is a lack of a comprehensive national strategy plan for the Bus Rapid Transit (BRT) technology or the sector as a whole. So, the absence of a national strategy plan for BRT poses several challenges and limitations. Without a clear and cohesive plan, the introducing BRT technology.

IV. Social, Culture, and Behaviour

Many individuals may be hesitant to use BTR (Bus Rapid Transit) technology, as passengers often prefer the flexibility of smaller buses. Small buses typically require less time to fill with passengers and move, compared to BTR systems which require a larger number of passengers and necessitate more time to move and depart.

V. Information and Awareness

There is no information and public awareness on the social, economic, and environmental benefits of BRT in the scope of the country stakeholders, labourers, drivers, and local people in this sector

VI. Technical

Absence of standardization, codes, and certification for new technology vehicles. In additional, there are no specialized personnel for the service and maintenance of BRT.

VII. Infrastructure

Poor infrastructure for the BRT system as the current infrastructure needs to be repaired or a new one established, considering the random urban expansion that happening recently

3.2.3 The Identified Measures for the Introduction of Bus Rapid Transit (BRT) Technology Option

The solutions and measures to overcome the challenges and barriers can be thought of during desk study with consideration of the context of the country as well as the discussions with stakeholders at relevant sectors separately

and together in the workshop to unify the opinions of all stakeholders to reach important measures for the identification of the barriers measures, this can be done particularly for publicly provided goods such as the BRT.
However, problem tree and solution tree are used in identifying the required measures and solutions for each barrier. (see Annex 1.7 – 1.8). The measures were categorized accordingly into financial and economic, and non-financial and non-economic measures, as shown in the tables below (Table 3-3 and table 3-4):

3.2.3.1 Economic and Financial Measures

Table 3-3: The proposed measures corresponding to the economic and financial barriers and expected benefits of BRT.

#	Barriers	Sub-barriers	Measures	Expected benefits
1	Financial and Economic	▪ Lack of financial donors for such a project	▪ Development of trade policies, legislations, and by-laws to motivate investment in the BRT system. ▪ Utilize the county's opportunities to fund the implementation of such a system through multilateral climate finance that supports financing low emission transport projects, such as GCF, GEF, CIF, etc	▪ Enhanced economic growth and trade opportunities. ▪ Increased private sector investment in the BRT system. ▪ Improved efficiency and effectiveness of the transport sector ▪ Access to additional funding for the BRT project. ▪ Reduced financial burden on the government.
		▪ High investment cost of BRT project	▪ Tax subsidies, and tariff regime policies.	▪ Reduced investment costs for the BRT project. ▪ Increased affordability and accessibility for commuters. ▪ Incentives for private sector participation in the BRT system
		▪ High inflation rate and inadequate financial policies	▪ Updating the regulations and policies of the transport sector, and developing specific policies for BRT deployment, and operation management, ▪ Development of financial mechanisms to fund the deployment of the technology	▪ Improved regulatory framework for the transport sector. ▪ Enhanced efficiency and safety of the BRT system. ▪ Better integration of BRT with other modes of transport. ▪
		▪ No BRT system market in the country	▪ Government participation in making incentives for travel private companies to invest or co-invest in the BRT systems	▪ Increased private sector participation and investment in the BRT system. ▪ Expanded coverage and improved quality of the BRT network.

				▪ Enhanced public transportation options for commuters.
		▪ The increased unemployment rate, where the low-income of local population (small bus owners), will lose their jobs has adverse effects not only on small bus owners' daily income but also on the tax that the transport sector gets from the drivers.	▪ Development just transition mechanism can be applied for small bus owners to overcome the adverse effects of the BRT deployment. This can be through employing them in the new BRT project, after carrying out a training program to qualify them to operate and be an effective component in the BRT system	▪ Mitigated negative impact on small bus owners' livelihoods. ▪ Smooth transition to the new BRT system. ▪ Job creation and training opportunities for affected bus owners.

3.2.3.2 Non-Economic and Non-Financial Measures

Table 3-4: The proposed non-financial measures corresponding to the non-financial barrier and expected benefits of BRT.

#	Barriers	Sub-barriers	Measures	Expected benefits
1	Legal and Regulatory	▪ Insufficient legal and regulatory framework for the transport sector especially public transport.	▪ Activation of the role of public transport instead of the current semi-public transport ▪ Set up a legal and regulatory framework to create a BRT market and enforce existing legislations/by-laws to regulate the transport sector	▪ Improved public transport services and infrastructure. ▪ Enhanced coordination and efficiency in the transport sector. ▪ Increased accessibility and affordability for commuters. ▪ Improved governance and regulation of the transport sector. ▪ Clarity and consistency in the legal framework for BRT operations. ▪ Enhanced accountability and compliance with transport regulations.
2	Communication and Coordination between the actors and stakeholders	▪ No coordination between the actors and stakeholders, in the same sector or with other sectors.	▪ Set a plan for coordination mechanism between relevant government institutions and various stakeholders including the private sector to invest in such technology	▪ Improved coordination and collaboration among stakeholders. ▪ Effective planning and implementation of the BRT system. ▪ Enhanced efficiency and integration of transport services.
3	Institutional and Organizational Human Skills	▪ Limited institutional and organizational capacity, and	▪ Create professional institutions to support technical standards for new technology such as	▪ Improved technical expertise and capacity for BRT system operation and maintenance. ▪ Adherence to quality standards and best practices.

		inadequate human skills	BRT transportation.	▪ Enhanced safety and reliability of the BRT system.
			▪ Set up education and training workshops for capacity building in all new technology transportation including BRT systems	▪ Enhanced knowledge and skills of professionals in BRT system planning and operation. ▪ Improved capacity to manage and maintain the BRT infrastructure. ▪ Higher quality of service and customer satisfaction.
		▪ The regular decision-making process for implementing BRT can be expected to be more bureaucratic and might cause delays and cost overrun	▪ Streamline regulatory and single-window policies to expedite the implementation of the BRT systems in the country	▪ Reduced bureaucratic processes and delays in implementing BRT projects. ▪ Timely completion of BRT infrastructure and services. ▪ Cost-effective implementation and reduced project overruns.
		▪ There is no national strategy plan for the technology or the sector itself	▪ Development of a national strategy for clean transportation and give priority to the adoption of the BRT systems. ▪ Integrate the technology into the national climate change policies and plans, such as LT-LEDs and NDCs	▪ Improved environmental sustainability and reduced GHG emissions. ▪ Enhanced integration of BRT systems into the national transportation framework. ▪ Alignment with climate change policies and goals.
4	Social, Cultural, Behaviour and low awareness	▪ Most people may be hesitant to use new technology such as BRT due to the waiting time where most people prefer using small buses that wait a few minutes to move	▪ Dissemination of information and public awareness on the BRT system and its environmental and economic benefits ▪ Provide innovative services	▪ Increased public acceptance and support for the BRT system. ▪ Improved perception of the environmental and economic advantages of using BRT. ▪ Shift towards sustainable and efficient modes of transportation.
5	information	▪ lack of information on the BRT in the scope of the country stakeholders, labourers,	▪ Establishment of Information Management Systems for the public transport	▪ Improved communication and information flow among stakeholders, labourers, drivers, and local people. ▪ Enhanced coordination and collaboration in the transport sector.

		drivers, and local people in this sector		▪ Increased transparency and access to information for all parties involved. ▪ Better decision-making based on reliable and up-to-date information.
6	Technical	▪ No standards, codes, or certifications for new technology vehicles.	▪ Setting up a centre for certifications, standards, codes, testing, and demonstration of new technologies such as the BRT. ▪ Development of manuals and guidelines for monitoring and testing the quality systems	▪ Ensure the adoption of standardized and certified technologies in the transport sector. ▪ Facilitate the testing and demonstration of new technologies, such as the Bus Rapid Transit (BRT) system. ▪ Promote innovation and technological advancements in the transportation industry. ▪ Enhance the quality, safety, and efficiency of vehicles and transportation systems. ▪ Establish clear guidelines and procedures for monitoring and evaluating the quality of transport systems. ▪ Ensure compliance with industry standards and regulations. ▪ Improve the overall quality and performance of transport systems. ▪ Enable continuous improvement and effective maintenance of the infrastructure and vehicles.
7	Infrastructure	▪ Poor infrastructure for the BRT system as the current infrastructure needs to be repaired or a new one established, considering the random urban expansion that happening recently	▪ Development a strategic plan for the infrastructure for a public bus transport system such as the BRT within major cities, and between governorates	▪ Provide a roadmap for the development and expansion of the BRT system within major cities and between governorates. ▪ Ensure proper allocation of resources and funding for infrastructure projects. ▪ Address the current poor infrastructure conditions and plan for necessary repairs or the establishment of new infrastructure. ▪ Accommodate the urban expansion and changing transportation needs of the population.

3.2.4 General Description of the Hybrid Electric Vehicle (HEV) Technology Option

One approach to lowering the CO_2 emissions from traffic is the hybridization of vehicles. A hybrid vehicle uses two or more distinct power sources, i.e., hybrid electric vehicles (HEVs) combine an internal combustion engine and an electric motor. Vehicles employed in urban areas like small passenger cars benefit from hybridization and show substantially lower CO_2 emissions, ranging from 23% to 43% depending on the traffic dynamics.

Hybrid electric vehicles (cars, buses, local delivery vans) are most feasible for use in urban traffic, where there is a frequent need for braking. Regenerative braking and electric motors of a hybrid car moving at a speed of 30-40 km / h lower CO_2 emissions by 33-40% compared to a car using conventional fossil fuels (liquefied petroleum gas, diesel oil, gasoline). Hybrid vehicles do not show significant improvements in fuel consumption when driven on highways. A large advantage of hybrid vehicles compared to other options for reducing GHG emissions in transport is the fact that no additional infrastructure investments are required.

There are hybrid vehicles in Yemen, solely imported by individuals, without a well-organized plan by the government to encourage the imports and use of hybrid vehicles for their various benefits. In addition, there are no hybrid vehicle suppliers in the country, and spare parts for such a technology are rare or non-existent. No regulatory system is present for such energy-efficient, fuel-saving, reduced CO_2 emissions, which regulate and facilitate such a technology. The hybrid vehicle has advantages over conventional vehicles since it is less dependent on fossil fuels and has lower operating costs and a lower maintenance cost compared to conventional vehicles. noticeable disadvantage is battery cost and maintenance.

3.2.5 Identification of Barriers to the Hybrid Electric Vehicle (HEV) Technology Option Promotion

To identify barriers to the HEV promotion, problem, and solution trees exercises were used. (Annex 1.9 – 1.10). Moreover, the identification of barriers also comprised desk studies that included national reports, economic and other relevant assessments of the technology; consultations with eminent experts in the sector and other stakeholders, and most importantly organizing dedicated stakeholder involvement and validation workshops inviting stakeholders from the government and private sector. The results of in-depth assessments of barriers facing such a technology are elaborated below. The barriers to the promotion of HEV were categorized accordingly into financial and economic barriers, and non-financial and non-economic barriers, as shown in the table below:

Table3-5: The proposed barriers corresponding to the economic and financial barriers and non-financial barriers for HEV

#	Category	Subcategory	Barriers
1	Financial and Economic	-	▪ The relatively high cost of the HEV
			▪ High interest rate for loans, adding to the high inflation make HEV not viable to most of the public
			▪ No market incentives to deploy HEV, together with no consumer incentives to buy HEV
			▪ limited HEV market in the country, and there are limited known suppliers of HEV in the country
			▪ There is no demand for HEV, and market information on HEV is poor
2	Non-Financial and non-economic	Legal and Regulatory	▪ Lack of clear policies, legislation, and by-laws regulating the import and use of HEV in the country
		Communication and Coordination	▪ Insufficient coordination between relevant ministries and possible HEV suppliers.
			▪ Lack of involvement of stakeholders in decision-making regarding transport policies
		Human Skills	▪ Lack of service and maintenance specialists for HEV
		Social, and Cultural Behaviour	▪ Lack of confidence in HEV ▪ Resistance to change due to unfamiliar technology, and wrong perception of new technologies.
		Information and Awareness	▪ Inadequate information, No dissemination of information to consumers on HEV performance, and public awareness about environmental and economic benefits, etc.

	Technical	▪ Inadequate guidelines and safety standards, codes, and certification
		▪ Lack of initiatives to set standards on emissions and fuel efficiency for new technology vehicles.
		▪ The technical capacity limitation of the electrical and mechanical engineering programs taught at the technical and academic institutions affects the quality of resource technicians available.
	Infrastructure	▪ Absence of the supporting infrastructure for introducing HEV into Yemen

3.2.5.1 Economical and Financial Barriers

The relatively high cost of the HEV comparing with fossil fuel vehicle, and high interest rate for loans, adding to the high inflation makes HEV not viable to most of the public. There are no market incentives to deploy HEV, together with no consumer incentives to buy HEV. Moreover, limited HEV market in the country, and there are limited known suppliers of HEV in the country and there is no demand for HEV, market information on HEV is poor. High interest rate for loans, adding to the high inflation make HEV not viable to most of the public

3.2.5.2 Non-Economic and Non-Financial Barriers

I. Legal and Regulatory

Lack of clear policies, legislations, and by-laws regulating for both importing and using of HEV in the country.

II. Communication and Coordination

Insufficient coordination between relevant ministries and possible HEV Suppliers in addition to the lack of involvement of stakeholders in decision-making regarding transport policies.

I. Human Skill

Lack of service and maintenance specialists for HEVs, this shortage can be a result of various factors such as low demand for specialized skills, or the relatively recent limited introduction of HEVs into the market.

II. Social, Cultural, and Behavioural

Lack of confidence in HEV, resistance to change due to unfamiliar technology, and wrong perception of new technologies by society. lack of confidence in their capabilities and reliability, resistance to change due to unfamiliar technology, and society's wrong perception of HEVs. Lack of trust in HEVs is rooted in doubts about their performance, durability, and safety. Resistance to change arises from discomfort with new technology and a preference for familiar systems. Society's wrong perception, fuelled by misconceptions about cost-effectiveness, environmental benefits, and maintenance requirements, leads to scepticism and reluctance to embrace HEVs.

III. Information and Awareness

Inadequate information on HEV, as well as Inadequate information, No dissemination of information to consumers on HEV performance, and public awareness about environmental and economic benefits, etc.

IV. Technical

Inadequate guidelines and safety standards, codes, and certification. The technical capacity limitation of the electrical and mechanical engineering programs taught at the technical and academic institutions affects the quality of resource technicians available. Lack of initiatives to set standards on vehicle emissions and fuel efficiency.

V. Infrastructure

Absence of the supporting infrastructure for introducing EV into Yemen

3.2.6 The Identified Measures for the Hybrid Electric Vehicle (HEV) Technology Option Promotion

Having established a thorough understanding of the barriers to HEV promotion, the next step was to analyse how these barriers can be removed or overcome; the measures will enable or motivate a particular course of action or

behavioural change to overcome the identified barriers. Since HEV is a consumer-provided good the market mapping approach – problem tree and market mapping, which were used for the identification of barriers, can also be used for the identification of solutions and measures to overcome these barriers. The measures for the promotion of HEV were categorized accordingly as financial and economic measures, and non-financial and non-economic measures, as shown in the table below:

3.2.6.1 Economical and Financial Measures

Table 3-6: The proposed measures correspond to the economic and financial barriers and non-financial barriers for HEV

#	Barriers	Measures	Expected benefits
1	The relatively high cost of the HEV	▪ Provide incentives to reduce HEV costs, and increase ownership of HEV	▪ Reduction in the financial barrier of high HEV costs, making it more affordable for consumers. ▪ Increased ownership of HEV vehicles, leading to a higher adoption rate of environmentally friendly transportation options.
2	High interest rates for loans, adding to the high inflation make HEV not viable to most of the public	▪ Set new financial policies to encourage the acquisition of HEV by average-income families	▪ Lower interest rates for loans, making HEV more financially viable for the general public. ▪ Increased affordability of HEV vehicles, enabling average-income families to participate in the transition to more sustainable transportation.
3	No market incentives to deploy HEV, together with no consumer incentives to buy HEV	Consumer incentives, such as: ▪ Exemption from registration fees, road-usage fees at registration, ▪ Concessional loans with extended periods, and low interest rate	▪ Reduced financial burden for consumers in terms of registration and road-usage fees, making HEV ownership more attractive. ▪ Increased affordability of HEV through concessional loans with extended periods and low-interest rates, encouraging more people to choose HEV vehicles.
4	Limited HEV market in the country and low known suppliers of HEV in the country.	▪ Market incentives by providing exemption from customs and excise fees on HEV, and spare parts (battery, electric motor, etc.)	▪ Availability of HEV vehicles and spare parts in the market, facilitating the growth of the HEV market in the country.
5	There is no demand for HEV, and market information on HEV is poor	▪ Start a public awareness campaign of HEV performance and its economic benefits. ▪ Government disincentives to the import of non-efficient pre-owned vehicles	▪ Reduced costs for importing HEV vehicles and spare parts, making them more affordable for consumers. ▪ Availability of HEV vehicles and spare parts in the market, facilitating the growth of the HEV market in the country.

3.2.6.2 Non-Economic and Non-Financial Measures

Table 3-7: The proposed measures correspond to the non-economic and non-financial barriers for HEV

#	Barriers	Measures	Expected benefits
1	Lack of clear policies, legislation, and by-laws regulating the import and use of HEV in the country	▪ Set up a legal and regulatory framework to create an HEV market and enforce existing legislations/by-laws to regulate the transport sector ▪ Prioritize the technology to be in the list of country priorities in the national climate change policies and plans, such as LT-LEDs and NDC	▪ Clarity and transparency in policies regarding HEV import and use, providing a conducive environment for the growth of the HEV market. ▪ Effective regulation of the transport sector, ensuring compliance with safety, environmental, and quality standards related to HEV vehicles.
3	Insufficient coordination between relevant ministries and possible HEV suppliers. Lack of involvement of stakeholders in decision-making regarding transport policies	▪ Set a plan for coordination and communication mechanisms between relevant government institutions and various stakeholders including the private sector to orient the deployment of the technology	▪ Enhanced coordination between all the stakeholders, especially the government and the car importers, which will be reflected in the deployment and affordability of the Technology
4	Lack of service and maintenance specialists for HEV	▪ Set up education and training workshops for capacity building in all new technology transportation especially, HEV and EV	▪ Improved the technical skills of the national labours to maintain the HEV, which will help to more deponent of the technology
5	Lack of confidence in HEV Resistance to change due to unfamiliar technology, and wrong perception of new technologies.	▪ Dissemination of information to consumers on the HEV performance, environmental and economic benefits ▪ Enforce car dealers to include factsheets on the HEV benefits. ▪ Enforce marketing campaigns (billboards, TV, Radio, newspapers, etc.).	▪ Increased awareness among consumers about the advantages of HEV, influencing their purchasing decisions. ▪ Greater acceptance and demand for HEV vehicles, leading to a shift towards more sustainable transportation options. ▪ Enhanced consumer knowledge about the benefits of HEV vehicles, enabling them to make informed choices. ▪ Increased transparency in the automotive market, ensuring that customers have access to reliable information about HEV technology.
6	Inadequate information, No dissemination of information to consumers on HEV performance, and public awareness about environmental and economic benefits, etc.	▪ The development of quality and standards for components of hybrid electric vehicles (HEVs). ▪ Ensuring the enforcement of quality standards to avoid importing poor-quality HEV systems. ▪ Creating manuals and guidelines for monitoring and testing the quality of HEV system	▪ Enhanced reliability and performance of HEV vehicles, leading to increased customer satisfaction and trust in the technology.

	Inadequate guidelines and safety standards, codes, and certification.	▪ The development of quality and standards for components of hybrid electric vehicles (HEVs). ▪ Ensuring the enforcement of quality standards to avoid importing poor-quality HEV systems. ▪ Creating manuals and guidelines for monitoring and testing the quality of HEV system	▪ Enhanced reliability and performance of HEV vehicles, leading to increased customer satisfaction and trust in the technology.
	Lack of initiatives to set standards on emissions and fuel efficiency for new technology vehicles.		
7	Limited technical capacity of the electrical and mechanical engineering programs taught at the technical and academic institutions affects the quality of resource technicians available.		

3.3 Linkages of the Barriers Identified (BRT & HEV Technologies)

The two technologies are interlinked in many ways. Simply by setting solutions/measures for the information and awareness barriers we can have the solutions/measures needed for some of the social, cultural, and behavioural barriers. These could apply to both transport technologies.

Information dissemination and public awareness are the tools to reach common people. The social, economic, and environmental benefits of the new technologies – the introduction of BRT and the promotion of HEV in the transport sector, can have a major impact on the perceptions of such technologies by the public.

The second linkage between the two technologies is the economic and financial barriers. Issuance of sound economic and financial policies, by-laws, and regulations can play an important role in the import of new transport technologies. Setting a subsidiary scheme for HEV, a loan scheme, and incentives, together with the exemption of registration, road tax, and annual test fees are crucial in the promotion of HEV.

The other most important linkage is the absence of a regulatory framework to deal with the use of the new technologies, which have fuel efficiency, and less or no GHG emissions. Also, the weak enforcement of regulations, and by-laws that regulate and manage the transportation sector. Developing a new regulation for vehicle tests, certification, and standards, with emphasis on fuel efficiency and less or no CO_2 emissions, is a crucial and urgent matter.

Another linkage between the two technologies is human skill and capacity building. It is obvious that without qualified personnel for both technologies, the transfer and diffusion of such new transport technologies in Yemen will not be fully accomplished. The right qualified operators, technicians, and demonstrators will hasten the much-desired goal, which is the transfer and diffusion of the two technologies in the market.

The infrastructure for mass public transportation such as BRT is not well developed. The government should prepare plans for the development of transport infrastructure for mass public transport such as the BRT, and future public transport such as under-ground and above-ground rail transport. All these should be incorporated into the future development plans of modern cities.

3.4 Enabling Framework for Overcoming the Barriers in the Two Technologies

As transport technologies continue to progress more transport methods need to be continuously adapted to meet the challenges occurring in transport demand and travel behaviour.

The introduction of new technologies in the transport sector is a must, to meet the continuous demand for safe, efficient, comfortable, fast, and fuel-saving, with economic, social, and environmental benefits.
Government institutions should develop a regulatory system that regulates the increasingly needed new technologies in the transport sector. It is well known that no economic and sustainable development can be achieved without the efficient functioning of the transportation system.

The current infrastructure for mass public transport such as – BRT, is inadequate and poor. Hence, the urgent need for the government is the construction of an adequate infrastructure, this could pave the way for financial funding efforts and investment opportunities for the BRT system.

The enabling environment for transport sector development and improvement can be summarized in the following:

I. Information and Awareness

An information and awareness campaign has to be coordinated between various stakeholders in the transport sector. An important factor for the wide-scale use and spread of the two technologies in the country, and the desired transfer and diffusion in the market.

II. Economic and Financial

Developing trade and financial policies that encourage investment in mass public transport such as – BRT, also, these trade and financial policies must meet the demand to enhance the import and use of new technologies that have less or zero GHG emissions. These can be done by reducing or exemption of customs, excise, tax, and fees on technologies. The maximization of the incentives of acquiring fuel-saving HEV and using public transportation such as BRT will be of great benefit to the commuters.

III. Policy and Regulation

A national policy should be developed for the enforcement of GHG mitigation-oriented technologies, such as economical fuel-saving, and less CO_2 emitter HEV. More focus should be given to public transportation regulations to be a suitable alternative to using private cars. The introduction of the BRT system can minimize transport congestion greatly, it can be affordable, fast, time-saving, and comfortable. A regulatory body should be established responsible for assuring correct implementation of such new technologies. These measures should impose law enforcement for tied regulations.

IV. Institutional & Organizational

The weak and poor performance of the government institutions is reflected in all sectors, including the transport sector. The proper implementation of a transport strategy requires a clear and efficient institutional and organizational set-up at the national level where:

- ✓ responsibilities for each institution-body are clearly defined,
- ✓ monitoring the proper functioning of each institution, and the enforcement of regulations is in place,
- ✓ proper coordination between various relevant government institutions,

By giving the authority for one central governmental institution, responsible for developing the public transportation, this can occur through collecting data, planning, monitoring, and evaluating. Noting that the most important point is to enforce the regulations.

V. Infrastructure

There is a need to rehabilitate the roads in major cities, for bus public transport, and to be able to absorb the high increase of private vehicles. Developing the infrastructure for public transportation such as Bus Rapid Transit (BRT) will help solve most of the transport challenges and barriers.

VI. Human Skills and Capacity Building

The government should set a plan for training programs to develop human capacity in all relevant transport institutions. This will help in developing the appropriate functioning and operation of various departments responsible for the transportation sector such as data collection, planning, monitoring, evaluating, and enforcement of regulations.

Table 3–8: Enabling framework for overcoming barriers for both BRT and HEV in transport sector, also the responsible government authority.

#	Enabling Environment	Measures Needed	Responsible Government Authority
1	National Economic and Financial	• Trade policies and by-laws • Tax, subsidies, and tariff regime policies • Regulation of financial sector institutions • Public investment policies • Commercial law and practice	• Ministry of Trade and Industry • Ministry of Finance and Customs Authority • Ministry of Trade and Industry
2	Human, Organizational, and Institutional Capacity	• Capacity-building programs of government authorities and institutions • Initiatives to enhance efficiency in government procedures and processes • Promotion of Trade associations, networks, organizations and alliances	• Ministry of Planning and International Cooperation • Ministry of Trade and Industry • Ministry of Transport
3	Research, Technical Capacity, and Infrastructure	• Technical standards, certification, and codes • Publicly funded research and development and training programs • Support for testing and demonstration facilities • Monitoring capacity programs • Infrastructure for public mass transport. • Rehabilitation of streets and roads.	• Ministry of Education. • Ministry of Technical Education. • Ministry of Transport. • Ministry of Planning and International Cooperation. • Ministry of General Works.
4	Information and Public Awareness	• Dissemination of information and public awareness on the social, economic, and environmental benefits of public mass transport such as BRT, and Hybrid vehicles HEV	• Ministry of Trade and Industry. • Ministry of Transport. • Ministry of Media.

Expected outcome and overall impacts:

The transition towards sustainable transportation systems, specifically through the implementation of Bus Rapid Transit (BRT) and Hybrid Electric Vehicles (HEVs), marks a pivotal stride in addressing environmental and economic challenges facing urban areas globally. And the expected outcome as the following:

- Reduced greenhouse gas emissions: The implementation of BRT and HEV systems can significantly reduce the emissions of greenhouse gases, such as carbon dioxide, by providing an alternative to conventional fossil fuel-based transportation. This reduction in emissions contributes to climate change mitigation efforts and promotes low-emission development.

- Improved air quality: BRT systems and HEVs produce lower levels of air pollutants compared to traditional vehicles. By adopting these sustainable transportation options, there is a potential for improved air quality, leading to better public health outcomes and a cleaner environment.
- Increased resilience to oil price fluctuations: BRT systems and HEVs are less dependent on fossil fuels, which makes them more resilient to fluctuations in oil prices. By diversifying the energy sources used for transportation, cities, and countries can reduce their vulnerability to oil price shocks and enhance their energy security.
- Green job creation and economic growth: The implementation of BRT systems and the adoption of HEVs can stimulate the growth of green industries and create employment opportunities in the manufacturing, maintenance, and operation of these sustainable transportation systems. This can contribute to economic development while promoting a transition to a low-carbon, sustainable economy.
- First step for transport sector decarbonization: Promoting the adoption of BRT and HEVs can act as the bridge between the convention facilities operated by fossil fuels, and low-emission transport. The hybrid will be the energy point to establish an enabling environment for transition into electrical vehicles. The BRT will help to enhance the infrastructure needed for the low-emission transport in the future, by promoting the adoption of the electrical BRT.

Water Sector

4. Water Sector

4.1 Preliminary Targets for Technology Transfer and Diffusion for Desalination and Rainwater Harvesting Technologies

The impacts of climate change and lack of access to potable water are some of the underlying causes of malnutrition in the country, undermining economic and social stability. While the current conflict has markedly increased Yemen's water scarcity, Yemen was one of the world's most severely water-stressed countries even before the conflicts.

Extreme weather events have destroyed irrigation facilities and led to the loss of agricultural livelihoods in Yemen, thereby increasing food and livelihood insecurity. Protracted conflict, climate-related disasters, and acute water shortages have exacerbated forced migration and displacement in the country.

The protracted conflict and the under-investment in water infrastructure today deprive millions of Yemenis of access to clean and drinkable water. Several underlying causes are contributing to exacerbating the water crisis in Yemen, including the proliferation of Qat as a cash crop which consumes more than 40% of Yemen's total renewable water resources and 32% of all groundwater withdrawals. The rate of groundwater overdraft is currently much higher (twice) than the recharge rate, and is increasing, bringing depletion of water reserves, inequity, and shortages (UNDP & ACACIA WATER, 2021).

Moreover, climate change impacts have become more visible, placing additional strains on water security. Estimates of future rainfall variability show that drought periods are likely to increase. Similarly, it is expected that a high rise in temperatures could lead to higher evapotranspiration rates. Rising sea levels have leaked into freshwater coastal aquifers, worsening the water supply of three of the country's major cities (USAID 2015).

Yemen has limited water resources. Hence, the protection of these resources from misuse and providing alternative resources have to be a high priority for the country's national water strategy and to the supporting international organizations. No other additional sources of water are available, so far, except rain, flood water and groundwater(Noaman, 2022).

Perceptibly, the shortage in supplying water for country needs, either domestic industrial or agricultural needs, is not only the result of misuse of the already scarce water resources and malfunction of the water resources management tools but also the result of the absence of strategic comprehensive executive plans to avoid or at least to alleviate the threatening crisis consequences. In fact, since the 1980s, there are no serious actions have been taken towards tackling the water problems countywide. Even after the appearance of abundant energy sources, oil, and natural gas, during the last four decades, no serious action has been taken yet.

The average Yemeni has access to only 140 cubic meters of water per year for all uses, while the Middle Eastern average is 1,000 m3/yr., and the internationally defined threshold for water stress is 1,700 cubic meters per year (Martin A. Abraham 2017). Groundwater is the main source of water in Yemen but the water tables have dropped severely leaving the country without a viable source of water (UNDP, 2022).

As it has been mentioned above, several underlying causes are contributing to exacerbating the water crisis in country, including the proliferation of Qat as a cash crop which consumes more than 40% of Yemen's total renewable water resources and 32% of all groundwater withdrawals, causing depletion of water reserves, inequity, and shortages (ICRC 2021).

A synopsis made for Aden to the year 2050 foresees population growth to 2,885,413 per capita and an increase in demand of 461,623 m3/d, while the total water production will increase to 161,113 m3/d. The shortfall in water supply is thus predicted to be 300,510 m3/d. So, to overcome this shortage it is necessary to build two new distillation stations

of the approximate capacity of 100,000 m3/d each, and to rehabilitate and upgrade the existing one in the Al-Sha'ab vicinity.

In the year 2000 and after, the Social Fund for Development and Public Work Project launched a campaign for restoration and improvement of the existing rainwater harvesting tanks in a number of districts of the midlands and in the proximity of highlands in order to help create additional non-conventional sources of water for the poor villagers. But after some time and for an unknown reason the campaign halted, a clear example is Al-Muflehi of Yafea/ Lahj Governorate (Lawrence & Sullivan, 2002).

With the rapid depletion of groundwater resources and rapid population growth, Yemen is on the verge of an untenable situation where only renewable water resources will be accessible. Therefore, more investment should be made in brackish water seawater desalination and rainwater harvesting. The desalination methods are membrane-based (e.g., reverse osmosis) and thermal-based (e.g., multistage flash distillation) methods. And what concerns rainwater harvesting from rooftop or mountain flat sheds is applied for domestic supply and supplementary irrigation, accordingly.

The TNA project at this stage aims to identify climate adaptation technology needs, to determine priorities that will be used to formulate a concrete climate adaptation project to increase climate resilience in the region, by assessing potential adaptation measures in the area to overcome barriers of all possible kinds that may constrain the transfer and diffusion of adaptation technologies.

The technology adoption process is affected by three dimensions: technology and its characteristics, organizational factors including top management support, technology skills and capabilities, and available financial resources and the regulatory and economic context (e.g., government incentives and regulation, competition, and customer demand.

The first dimension that can affect the take-up of technology is organizational drivers such as improving operational efficiencies, making cost savings, enhancing the people experience, and developing a culture of innovation (CPA Australia, 2021, p. 20).

Therefore, people-related issues, such as perceived knowledge, skills, experience, motivations, and mindset, are a major sub-area within the organizational dimension that can affect the adoption of new technologies.

In this regard, the two technologies have the capability to address the water scarcity challenges by reducing the overuse of groundwater for residential, agricultural, and commercial purposes by providing new alternative and renewable water resources.

The target of production that Yemen aims to achieve from these two technologies are in the following table:

Table 4-1: Technologies and Preliminary target for prioritized technologies (Seawater Desalination Plants, Rainwater Harvesting)

#	Prioritized technology	Preliminary target
1	Seawater Desalination Plants	Several studies showed that reducing the dependency on groundwater by finding a renewable and sustainable alternative is the only option to address the water scarcity in that the exacerbated by climate change impacts. Desalination is the ideal option for this purpose, especially in the coastal zones. However, there are many barriers that hinder adoption in a large scale. Thus, the preliminary target is to enable Yemen to produce water of 165,000 m^3 per day through seawater desalination plants by 20235
2	Rainwater Harvesting	Local communities in the highlands depend on groundwater for their water demands and rainwater for their agricultural and livelihood activities. Therefore, it is necessary to enhance their capacity to efficiently utilize the

		rainwater. For this purpose, rainwater harvesting is the ideal option that can produce this service. The preliminary target is to support the local communities to store 100,000m^3 per year from rainwater by 2035.

4.2 Barrier Analysis and Possible Enabling Measures for both Desalination and Rainwater harvesting

Previously, in the TNA action report four adaptation technologies were identified based on the selected criteria. The technologies have been arranged and prioritized according to the ranking process for technology options and came up with a top list of four ranked technologies under adaptation for the water sector: saline water desalination, rainwater harvesting, diversion channels, and wastewater recycling and reuse.

Essentially, the prioritized technologies reflect the viewpoints of the stakeholders of different backgrounds and indicate the crucial need for one or another technology to meet their local requirements. For example, saline water desalination is appropriate mostly for coastal zones and the adjacent lowland areas, while rainwater harvesting is applicable for midlands and highlands of the country where rainfall is more frequent. Diversion facilities and channels are appropriate for most areas of the country where they are required to divert perennial streams and flood waters to where they are needed. The same thing may be said about the reuse of treated wastewater, it is opportune where possible, where the effluent volumes are economically feasible.

Of these four technologies only two have been considered as the most important and conceivable to be adopted, at least for the time being, and they are;

(1) Saline water desalination, and
(2) Rainwater harvesting techniques.

Categorization of Barriers into Major Thematic Categories and Sub-Categories:

1. Financial and economic; cost, feasibility, investment, local market conditions, market study.
2. Technical; Accessibility, reliability, complexity, human skills; available, prepared or employed from outside the project (at least for the beginning).
3. Institutional and legalization; legal and regulatory issues, the existence of laws and legislation, Institutional and organizational capacity, supervision, support and sustainability
4. Socio-cultural and behavioural issues; Removing suspicion or fear of new technologies.
5. Communication between stakeholders; speed of information exchange and response.

The following steps were followed for each technology to execute the task:

1. Identification of all possible barriers through literature survey, discussions with the sectoral working group and workshop brainstorms considering economic assessments, environmental impact, etc.
2. Selection of the most essential barriers
3. Categorization of the selected barriers
4. Developing measures to overcome barriers by translating barriers into solutions

Barriers are identified through a desk study of strategies and other relevant documents to identify the main reasons why desalination and rainwater harvesting technologies are not currently widely used, and why the private or public sectors have not invested significantly in them. The desk study was conducted by the TNA consultants with the assistance of relevant experts and stakeholders. Primary information was collected from the technology selection process as well as from other studies. Market mapping also helped in identifying the barriers. The selected barriers were finalized in a Workshop including stakeholders and experts from the government and private sector.

Barriers were identified by reviewing all available data concerning the desalination technology, surveying the local market searching the internet for international manufacturers, and taking an overview of the status of the technology

in the region. What concern rainwater harvesting technology, the task was easier because it is traditional in the country and practiced since ancient times, and the main issues to hint were how to improve the tools, storage, conveyance, and quality of the harvested rainwater for domestic supply, particularly in the rural communities.

The private sector has invested to some extent in desalination, in particular in reverse osmosis RO because of the increasing demand shown in the last two decades for household units and small to medium commercial units. Mostly, these units were customized just to improve the tap water quality to meet the demand for drinking water for individual families and small communities in a limited scale, but not to convert seawater or brackish water into drinkable. The only attempts were made to convert seawater into drinkable in the eighties of the last century in two thermal electric stations one in Aden with 24,000 m3/day capacity and another one in Al-Makha.

Enabling measures were identified in a workshop with the same group that has been involved in the barrier analysis. The inputs to the workshop include:

1. Consultant's own experience of working on such issues recently, including TNA, policy making from other countries and information available on the web.
2. Executive measures related to desalination in particular followed by neighbouring countries.
3. Solutions that came to mind during the barrier identification and decomposition process.
4. The market mapping tool will also be used for the identification of measures.

4.2.1 General Description Desalination Technology

The chemical process of changing seawater into potable or fresh water is called desalination. Thermal distillation and membrane processes are the two main approaches used around the world to desalinize water. Desalination processes may be used in municipal, industrial, or commercial applications. With improvements in technology, desalination processes are becoming cost-competitive with other methods of producing usable water to respond to a growing demand. Stand-alone desalination plants can use renewable energy to operate. The pure water that is obtained after desalination must be re-mineralized to be adequate for human consumption. The concentrated brine produced in desalination processes needs to be disposed of properly.

The feed water for desalination processes can be seawater or brackish water. Brackish water contains more salt than fresh water but less than saltwater. Brackish water is commonly found in estuaries, coastal plains, and aquifers, which are stores of water underground. Bot technologies need energy to operate and produce freshwater.

Figure 4-1:Main inputs and outputs in a desalination process (Clayton2007)

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Thermal distillation technologies are widely used in the Middle East, primarily because the region's petroleum reserves keep energy costs low. The three major, large-scale thermal processes are multistage flash distillation, multi-effect distillation, and vapour compression distillation. Another thermal method, solar distillation, is typically used for very small production rates (Félicien Mazille 2010).

Membrane distillation is an emerging membrane-based desalination technology. These systems treat the feed water by using a pressure gradient to force the water through membranes. The three major membrane processes are electrodialysis, electrodialysis reversal, and reverse osmosis.

The lack of dissolved minerals in the high-purity water produced by desalination processes raises some problems. High-purity water tends to be highly reactive and, unless treated, it can create severe corrosion difficulties during its transport in conventional pipelines. Also, untreated desalinated water cannot be used directly as a source of drinking water. A certain degree of remineralization is necessary in order to make the water palatable and for re-introducing some essential ions required for health considerations.

Both thermal and membrane desalination processes produce a stream of brine water that has a high concentration of salt and other minerals or chemicals that were either removed during the desalination process or added to help pre-treat the feed water. Options for discharging the brine include discharge into the ocean, injection through a well into a saline aquifer, or evaporation. Each option has advantages and disadvantages. In all cases, the brine water should have a minimal impact on the surrounding water bodies or aquifers. Specific considerations for the water quality include saline concentration, water temperature, dissolved oxygen concentrations, and any constituents added as pre-treatment.

The costs of desalination vary significantly depending on the size and type of the desalination plant, the source and quality of incoming feed water, the plant location, site conditions, qualified labour, energy costs, and plant lifetime. The capital cost includes the purchase cost of major equipment, auxiliary equipment, land, construction, management overheads, and contingency costs. The capital costs for seawater desalination plants have decreased over the years due to the on-going development of processes, components and materials. Annual running costs consist of costs for energy, labour, chemicals, consumables and spare parts. The energy costs strongly affect the running costs for thermal processes. Thus, distillation costs fluctuate more than reverse osmosis as they depend on changing energy costs. In regions where energy is fairly expensive, reverse osmosis is a favourable choice compared to any other thermal process due to its lower energy consumption(Shaheen & Cséfalvay, 2024).

As with all new technologies, progress in desalinating water has been rapid. Whereas it cost about $9.0/m3 to desalinate seawater around 1960, the costs are now around $1.0/m3 for the multi-stage flash distillation process. For reverse osmosis, the most popular method, the costs have fallen to $0.6/m3 for brackish water desalination (Zirrahi et al., 2024).

Ten years ago, desalinated water cost more than $2 per $1m^3$, but today, the range is $0.44 to $1.1 per $1m^3$.
Desalinated water tends to be more expensive than other freshwater sources due to high energy use and capital costs. However, costs may come down in future with technological improvements and economies of scale. The cost of a desalination plant depends on the size of the plant and the type of technology used. The cost of a small plant is around $1 million and the cost of a large plant is around $25 million (Ashie Akpoji, SFWMD, Quora 2024).

4.2.2 Identification of Barriers to Desalination Technology

Referring to the previous activities of the consultant and the available information about desalination, its types and scales of barriers cannot be identical in terms of availability, accessibility, applicability, and feasibility for individual investors or clients. The variety of methods, instruments, and sources of energy is one of the main barriers to the wide dissemination of technology. There are approximately seven types of thermal desalination and three types of membrane desalination, including reverse osmosis. Other barriers are related to the scale of technology, starting from household units and not ending with multistage thermal desalination of large capacity. Therefore, the identification of barriers to desalination has been made by collecting data from all possible sources including the internet, available literature, previous studies, and discussions with experts and personnel of the electrothermal station at Al-Sha'ab. . The outcomes from the validation workshop of stakeholders, a survey of the related official entities, and direct talks

with the representatives of the private sector; importers, wholesalers, retailers, and owners of commercial RO units were analysed by the TNA team and concluded in this report. Moreover, problem and solution trees were used to identify the relationships between all the barriers and the available measures.

Categorization of Barriers to Desalination Technology

The barriers of this technology may be categorized as:

(i) Economic and financial barriers
(ii) Non-financial barriers, which could include:
  a. Capacity building
  b. Legal and regulatory
  c. Technical, institutional, and policymakers' awareness

As a result of the above process, the following main barriers were identified:

1) High Capital and Installation cost
2) High Loan interest
3) Absence of Subsidy programs
4) Shortage in Legislation and regulation
5) Desalination statement is not included in the Water law of 2002
6) Scarcity of skilled labour to install, operate and maintain the systems
7) Absence of local manufacturers of RO membranes and systems.
8) No up-to-date strategies and no clear future plans concerning desalination exist
9) Limited private sectors engagement in the investment, especially in large-scale projects
10) Absence of state investment and initiatives to boost large scale desalination projects
11) Absence of guarantees and attractive incentives for local or other investors in this field.

Table 4-2: The proposed barriers corresponding to the economic and financial category and non-financial category for Desalination

#	Category	Sub-Category	Barrier
1	Economic and Financial	Financial and economic	▪ High capital and installation cost
			▪ High Loan interest still
			▪ Inadequate subsidy programs
			▪ Lack of capitals for large scale projects
			▪ Absence of funds for international tenders
			▪ Absence of guarantees and incentives
2	Non-Financial	Capacity building	▪ Lack of training program locally or abroad for the future operators and maintenance labours
		Legal and regulatory	▪ Shortage in clear articles in water law of 2002 concerning the technology
			▪ No statement concerning desalination
			▪ Inactive quality control regulations
		Policymakers' awareness	▪ Inadequate awareness of the existing desalination technologies
		Technical	▪ Absence of local manufacturers of the membranes, carbon filters and other parts
			▪ Outdated strategies and plans
		Institutional	▪ Feeble investment of private sector in large scale desalination for domestic supply
			▪ Lack of institutional and policy support.
			▪ Lack of energy needed to supply the desalination plants to meet the operation requirement.

4.2.3 Description of Barriers to Desalination Technology

4.2.3.1 Economic and Financial Barriers

I. High capital and Installation Cost

High capital cost with low revenue of annual return extends the cost recovery period. Therefore, large-scale projects can be hardly achieved unless there is state investment. Individual investors, regardless of the size of their businesses, will mostly not prefer to invest in such projects without official guarantees of all kinds from the government side.

And that's because desalination plants require significant upfront investments in infrastructure, including the construction of intake and outfall systems, pumps, pipelines, and treatment facilities.

The installation cost is one of the most important factors in investment decision-making. Also, high installation costs associated with price fluctuations and inflation affect equipment costs and production marketing, making the technology unattractive to investors. So, there should be advanced incentives of all possible kinds to motivate the investment in the technology.

II. High-Interest Loans

Interest rates on loans are still high and do not help in promoting investment in desalination technology. Besides, due to the project risk, uncertain revenue streams, in addition to limited financing options, and capital-intensive nature of the technology, which is considered one of the salient barriers to the adoption of this technology. State intervention in this issue is crucially vital to lower loan interest rates to encourage investment in such needed technology. Loan interest rates in the country are still high enough to discourage investors in the technology. Moreover, the existence of two banking systems aggravates the situation. Therefore, eliminating or at least reducing import duties, facilitating loans, reducing bank interest rates, and alleviating financial restrictions altogether may help technology promotion and investment.

III. Inadequate Subsidy Programs and grants for large-scale projects

The social and political unrest in the country with unstable governance and unactive government connections do not help allocate enough funds for large-scale projects of such kind and size or less. So, subsidies from this are impossible at least for the time being. In addition, there is no guarantee that the allocated fund will be sufficient due to price fluctuation, money inflation, and economic recession. So far, support may be expected from international donors, UN affiliates, NGOs, and others working in the country's organizations.

IV. Absence of Funds for International Tenders

First, a large-scale desalination project needs to conduct a feasibility study followed by tender document preparation and then tender announcement for local and international contractors and investors. All these procedures require finance, which is rare so far.

V. Absence of Guarantees and Incentives

Non-market goods comprise large components and equipment of specific orders that can only be provided directly by the manufacturer or contractor except for some part through niche market. Here guarantees and incentives may be made for the overall completion of the project or as stated in the contract document.

4.2.3.2 Non-Financial Barriers

I. Capacity Building

Lack of training program locally or abroad for the future operators and maintenance labourers. Proper operation is the main objective of desalination systems, but training in this aspect has not been provided yet. So, it is very important to organize such local training programs. There are no experts specialized in large-scale desalination technology, design, installation, operation and maintenance, but there are a few numbers of engineers and technicians trained to install, operate and maintain household RO units and med-size commercial units.

II. Legal and Regulatory

- **Shortage in clear article in Water Law of 2002:** The existing law of water ratified in August 2002, but the implementing regulations have not been issued or ratified yet. And the draft document of implementing regulations is still obsolete and doesn't suit the current situation associated with water issues.
- **No Statement Concerning Desalination in the Water Law of 2002:** Using desalinated seawater as an unconventional source to cover the shortage in drinking water supply has not been mentioned in the Water Law of August 2002 or any other legislative document since then.
- **Inactive Quality Control Regulations:** Axiomatically, the Ministry of Water and Environment is the authorized body in charge of issuing regulations on desalinated water quality standards and quality control. The Local Water Supply and Sanitation Corporation (LWSSC) has a well-equipped water testing laboratory at Al-Barzakh in Khormaksar, Aden. Operating costs are the main barrier.

III. Policymakers' awareness

- **Inadequate awareness of the existing desalination technologies:** Awareness of the large-scale desalination technologies is not promoted sufficiently in Yemen at all levels due to it still maturing.

IV. Technical

- **Absence of Local Manufacturers of the Membranes and Carbon filters:** Absence of local manufacturers of the membranes, carbon filters, and other parts Also, chemicals for water processing and their containers of steel, fibreglass and polyethylene. The barrier here is importing procedures of raw materials and equipment due to increasing the cost of transportation, customs duties. Other barriers are due to the continuous rise of fuel prices and inflation.
- **Lack of energy needed to generate the desalination plants:** The current energy capacity is limited and cannot meet the residential demands of electricity power. Therefore, it will not be sufficient to supply the operation of desalination technology, especially the large scale which requires a huge amount of energy to generate it. Therefore, the lack of energy will raise the cost of the technology installation, and operation as well as the investment costs.

V. Institutional

- **Outdated strategies and plans:** Old strategies and plans are one of the institutional barriers that constrain steps or delay the actions towards rapidly developing desalination technology and technology transfer, large scale in particular. Due to desalination was not one of the top prioritizing technologies in the strategy.
- **Feeble investment of the private sector in large-scale desalination projects:** Households RO and small and medium-scale mostly RO desalination businesses have been flourishing in the country since the 1990s, but the dimensions of the number of the components of large-scale desalination have small or limited space in the market interactions and does not attract investments to this business yet.
- **Lack of institutional and policy support:** Absence of institutional support to formulate policies to regulate and facilitate to development of desalination technology business and manufacturing in the country.

4.2.4 Identification of Measures for Desalination Technology

Barriers to desalination technology can be overcome through a combination of the following economic and financial measures, and non-financial measures Table 4-3 presents the proposed measures to overcome the economic and financial barriers and Table 4-4 presents the proposed measures to overcome the non-financial barriers.

4.2.4.1 Economic and Financial Measures to Overcome Barrier to Desalination

Table 4-3: The proposed non-financial measures corresponding to the non- financial barrier and expected benefits of Desalination

#	Economic and Financial Barriers	Proposed Measures	Expected benefits

1	High Installation Cost	▪ Exempting import duties on this technology. ▪ Eliminate or alleviate Taxes. ▪ Encourage the private sector to manufacture some components locally. ▪ Facilitate access to other sources of financing; banks and other financing organizations, under the climate finance channels, such as GCF, GEF, etc	▪ Reduce the overall cost of installation and make it more affordable for implementation. ▪ Lowering the financial burden associated with the technology would encourage its adoption. ▪ Job creation, economic growth, and reduced dependence on imports. ▪ Provide additional funding options for implementing the technology.
2	High Loan Interest	▪ Development of financial mechanisms to support the deployment including grants, low-interest loans, and possibly guarantees.	▪ Make funding more accessible and affordable for the deployment of desalination projects. ▪ Attract private investors and stimulate the growth of the desalination sector.
3	Inadequate Subsidy Programs and Absence of funds for international tenders	▪ Build partnerships with local and global multilateral funds to support the implementation of desalination projects on large and small-scale levels	▪ Provide financial support for implementing desalination projects on both large and small scales. ▪ leverage the expertise of global organizations and resources to overcome financial barriers and promote the implementation of desalination projects.
4	Lack of Capital for large-scale projects	▪ Joint venture, public contribution, and shareholding companies	▪ Attract the necessary capital investment for desalination projects. ▪ Involve private sector companies that can bring in expertise, technology, and financial resources to support the development of large-scale desalination projects.
6	Absence of Guarantees and Incentives	▪ Attract investors by offering guarantees and incentives of all possible kinds	▪ Offering guarantees and incentives of all possible kinds can attract investors and promote the development of desalination projects. ▪ Providing financial security and benefits can mitigate risks associated with desalination investments, encouraging more private sector participation.

4.2.4.2 Non-financial measures to Overcome Barrier to Desalination

Table 4-4: The proposed measures corresponding to the economic and financial barriers and expected benefits of Desalination

#	Economic and Financial Barriers	Proposed Measures	Expected benefits
1	Lack of training programs locally or abroad for future operators and maintenance personnel	▪ Organizing intensive training courses for local engineers and personnel by qualified experts from technology manufacturers. ▪ Make a global partnership with international organizations to gain capacity building and training programs on the desalination technology	▪ Updating strategies and plans and incorporating new desalination technologies can lead to more efficient and sustainable desalination processes.

2	Shortage in a clear article in Water Law of 2002 and No statement concerning desalination	▪ Government enforcement of laws and legislations and overcoming the shortage by revising the clauses, and by authorized power of law. ▪ Revision must be done to the legislation and regulatory system concerning the Law of Water of August 2002.	▪ Research and studies provide valuable information on the economic, social, and environmental impacts of large-scale desalination projects.
4	Inactive quality control regulations	▪ Activate the quality control authority and support by all means LWSSC laboratories	▪ Efficient and effective desalination systems
5	Inadequate awareness of the existing desalination technologies	▪ Disseminate awareness by the traditional and internet mass media, organize lectures, and hold workshops on the technology.	▪ Enhanced awareness of policymakers about the importance of desalination technology
6	Absence of local manufacturers of the membranes, carbon filters, and other parts	▪ Encourage local businessmen to invest in the manufacturing of the parts of the system for small-scale projects and to develop businesses of this kind.	▪ Wide expansion of the small-scale desalination projects in Yemen
7	Outdated strategies and plans	▪ Update the strategies and plans and refurbish ideas about new desalination technologies aspects. ▪ Integrate the technology into the national climate change plans and policies, such as NAPs and NDCs.	▪ Updating the water policies and strategies will lead to integrating climate change impacts on the water sector, as well as the need for desalination to address water scarcity due to the implications of climate change. ▪ Integrating desalination technology into national climate change plans and policies can contribute to climate mitigation and adaptation goals, and help to finance it through the climate change channels
8	Feeble investment of the private sector in large-scale desalination for domestic supply	▪ Development of feasibility studies and research about desalination to assess its economic, social, and environmental impacts	▪ Development of feasibility studies and research about desalination can provide valuable information on the economic, social, and environmental impacts of large-scale desalination projects. ▪ Raise the awareness of the policymakers about the importance of such technology deployment to address the water scarcity and vulnerability in the country.
9	Lack of institutional and policy support.	▪ Institutional support and formulation of policies to regulate and facilitate the development of desalination technology business and manufacturing in the country. ▪ Establishment of a department\ unit on the water policies at the Ministry of Water and Environment, in order to develop and update the water policies.	▪ Institutional support and formulation of policies to regulate and facilitate the development of desalination technology businesses can create a conducive environment for growth and innovation. ▪ Establishing a dedicated department or unit on water policies can ensure continuous development and updating of water policies, fostering a

			supportive framework for desalination technology.
10	Lack of energy needed to generate the desalination plants	▪ Supporting the investment in renewable energy for desalination purposes and integrating it into the agenda of the renewable energy plans of the government	▪ promote the use of sustainable energy sources, reducing the environmental impact of desalination and increasing energy efficiency. ▪ Promote the Water and Energy Nexus to address the climate change issues

4.2.5 General Description of Rainwater Harvesting Technology

Methods of water harvesting from the mountain flats in many regions of Yemen have been known since ancient times as one of the methods used to provide drinking water as well as for agriculture. The traditional practice of water harvesting and documentation of most of the mowers in the above-mentioned area, with consideration of the possibility of maintaining and developing them due to their role in the lives of the population. In fact, in number of cases the harvesting area has become heavily populated and the harvested rainwater has become susceptible for anthropogenic pollution. Therefore, the rooftop rainwater harvesting is considered as a good alternative to provide drinking water to people in these areas. So, it is necessary to attract the attention of all bodies of concern; officials, NGOs, donors to help locals, who are mainly villagers, to set up their own rainwater harvesting systems collectively or individually in order to secure drinking water to some reasonable extent.

Hundreds of years ago, residents used different rainwater harvesting methods to provide drinking water as well as to irrigate agricultural lands of limited area in the region. They built various facilities for that to hold water, store it, and direct it to agricultural fields. With obsolescence, lack of maintenance, and neglect of these facilities, due to conditions the region went through in the past, this led to some of them have partially or completely deteriorated and others have been ineffective, and the process of constructing similar effective facilities had almost stopped before that, although it has recently returned slowly and often individually and less effectively, primarily to provide drinking water.

In Yemen in the ancient time the rainwater harvesting especially in mountainous areas has been implemented by making small traditional dams, dykes, cistern, Majel, Karief and Oqmas. These traditional structures were used for both domestic water supply and agricultures uses. In the highest mountains the rainwater harvesting was from roofs, like Masjed roofs, from rock surfaces, and from mountains slope. Rainwater harvesting applicable for midlands and highlands of the country where rainfall is more frequent as shown in the isocheimal map of average rainfall *Figure 4-2.*

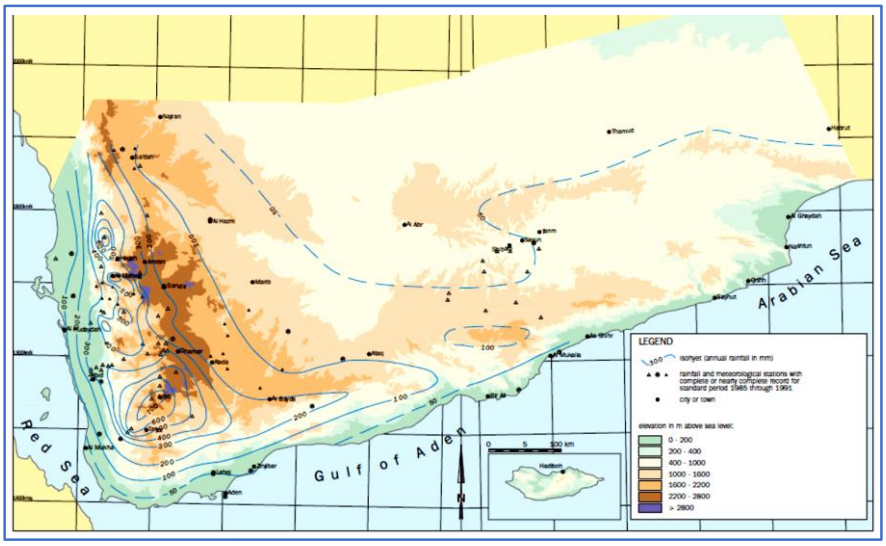

Figure 4-2:. Isocheimal map of average annual rainfall (Jac van der Gun 1995).

A rainwater harvesting system comprises components for collection, conveyance, filtration and storage.
Roof top rainwater harvesting can co- exist with and provide a good supplement to other water sources and utility systems, thus relieving pressure that exerted on ground water.

Rainwater harvesting provides a water supply for the urban areas, where there is no coverage by water supply network mainly during rainy season and the water received is free of costs, so the use of this water significantly reduces water bills for purchased water from municipal supply.

Traditional harvesting of rainwater is energy saving technique, and yet energy conserving since it does not require any additional source of energy to operate so far.

Rainwater collected from roof and stored in underground or on ground storage tanks helps in compensating the increasing demand for water in urban areas in scarcity period, and that collected from mountainous flat sides is covering the shortage in irrigation of agricultural land nearby and sometimes this collected rainwater is used for groundwater recharge.
Rainwater Collection in ponds through the water ways inside the city will contribute to recharging groundwater as well as for gardening and street trees irrigation instead of watering them by groundwater.
This technology is suitable for use in all areas as a mean of augmenting the amount of water available. It is most useful in arid and semi-arid areas where other sources of water are scarce, like city of Sana'a where the harvested water from the roofs will cover 17.5% from the total demand of the city population (WEC, Sana'a University, 2011).
Rainwater harvesting provides a source of water at the point where it is needed. It is owner operated and managed. The construction of a rooftop or catchment rainwater harvesting system is simple, and local people can easily be trained to build one with minimum cost.
The technology is flexible. The systems can be built to meet almost any requirements. Poor households can start with a single small tank and add more when they can afford them corresponding to the rain harvesting area. Running costs are low, Construction, operation, and maintenance are not labour-intensive.

4.2.6 Identification of Barriers to Rainwater Harvesting Technology

Despite the importance of rainwater harvesting in water conservation for agricultural and household purposes in rural areas, several barriers hinder its widespread in the country, especially in the highlands. Moreover, this technology is needed for irrigation systems, particularly the coffee farms, which highly depend on the rainfall seasons in the highlands parts of the country. The main barrier to rainwater harvesting deployment is more related to the construction

and capital costs and the lack of planning, which are results of the institutional weakness in the country. For more details, the barriers of this technology can be categorized as:

A. Economic and financial barriers
B. Non-financial barriers, which could include:
   - Capacity building
   - Legal and regulatory
   - Technical, institutional, and policymakers' awareness

As a result of the above process, the following main barriers were identified:

1. Capital and installation cost, and revenue.
2. Inadequate access to financial resources
3. Lack of legal and regulatory issues (the existence of laws and legislation)
4. Insufficient institutional, and technical capacity
5. Poor communication between stakeholders, speed of information exchange and response
6. Insufficient institutional framework and no comprehensive and strategic water policy such as rural development policy, drinking water needs of rural population not addressed
7. Lack of water distribution policy throughout the wadi basins
8. Low or absent water tariff
9. Rivers running dry for some months in the year
10. Socio-cultural and behavioral issues
11. Discrimination against independent water consumers or users
12. Information and awareness
13. Technical issues, accessibility, reliability, complexity, difficult to use, Difficult to improve Productivity.

Table 4-5: The proposed barriers corresponding to the economic and financial category and non-financial category for Desalination of Rainwater Harvesting

#	Category	Sub-Category	Barrier
1	Economic and Financial	Financial	▪ Capital and Installation cost
			▪ High loan interest rates
			▪ Inadequate subsidy programs
2	Non-Financial	Capacity building	▪ Lack of training program for future operators and maintenance personnel
		Legal and regulatory	▪ Shortage in clear article Water Law of 2002 in terms of utilization of rainwater harvesting
			▪ No clear article concerning rainwater harvesting in the Yemeni plans, policies, and regulations
			▪ The absence of integrated water resources management (IWRM) regulations and plans, that can control and monitor the use of all the available resources for efficient water management
			▪ Unactive Quality Control Regulations
		Policymakers Awareness	▪ Inadequate awareness of the existing rainwater harvesting technologies
		Technical	▪ Lack of simply maintained purification filters, carbon filters, and other parts
		institutional	▪ Outdated strategies and plans
			▪ Weak private sector engagement in supporting the technology
			▪ Lack of institutional and policy support: ○ The lack of specific policies, regulations, and guidelines. ○ Insufficient institutional capacity at the governmental level ○ Lack of coordination mechanisms for collaboration and coordination among various stakeholders, especially between the relevant ministries and authorities responsible for this technology deployment

4.2.7 Description of Barriers to Rainwater Harvesting Technology

4.2.7.1 Economic and Financial Barriers of Rainwater Harvesting

I. Capital and Installation Cost

The capital and installation cost for rainwater harvesting is not so high but difficult to allocate funds for such projects with limited sizes and scanty revenues of annual return extending the cost recovery period as well as its dependent upon rainy seasons. Thus, it can be a barrier for some individuals or communities, especially those with limited access to financial resources, particularly in low-income areas or regions. Therefore, individual investors regardless of the size of their business will mostly hastate investment without official subsidies and guarantees from the government side.

On the other hand, price fluctuations and inflation affect equipment costs and revenue collection, making the technology not attractive to investors. So, there should be incentives of all possible kinds to motivate investment in this technology.

II. **High Loan Interest**

Interest rates on loans are still high and do not help in promoting investment in rainwater harvesting technology. The high loan interest rates increase the overall cost of financing the project. This effect on a greater financial burden on individuals, communities, or organizations seeking to implement rainwater harvesting, especially for those with limited financial resources (low-income areas or regions). Thus, the loan interest rates may deter potential investors from pursuing rainwater harvesting as a viable solution for water management to hinder the realization of the potential benefits of rainwater harvesting, such as water conservation, improved water availability, and resilience to water scarcity.

State intervention in this issue is crucially vital by lowering loans' interest rate to encourage investment in such technology. Loan interest rate still high enough to discourage the investors in the technology. Therefore, facilitating loans, and reducing bank interest rates may help dissemination of the water harvesting technology.

III. Inadequate Subsidy Programs

Inadequate subsidy programs can also impede the scalability of rainwater harvesting initiatives. Unfortunately, the social and political unrest in the country with unstable governance and unactive government organisations, subsidy from which impossible at least for the time being. So far, support may be expected from international donors, UN affiliates, NGOs and other working in the country organizations.

4.2.7.2 Non-Financial Barriers of Rainwater Harvesting

I. Capacity Building

There are few engineers, technicians and skilled workers in rainwater harvesting technology, construction, operation, and maintenance. Due to lack of training programmes for engineers and personnel that cover the technical aspects of rainwater harvesting, including system design, installation, operation, and maintenance. These programs should provide hands-on training and practical experience to ensure that participants gain the necessary skills and knowledge. The training should focus on the specific challenges and requirements of rainwater harvesting in the local context.

II. Legal and Regulatory

- **The absence of the integrated water resources management (IWRM) regulations and plans,** that can control and monitor the use of all the available resources for efficient water management
- **Unactive Quality Control Regulations:** Obviously, the Ministry of Water and Environment is the authorized body in charge to issue regulations of harvested rainwater quality standards and quality control factors. The Local Water Supply and Sanitation Corporations LWSSCs in many governorates have a well-equipped water testing laboratories and may help in monitoring the water quality periodically.

III. Policymakers Awareness

- **Inadequate Awareness of the Existing Rainwater Harvesting Technologies:** Awareness of the rainwater technologies is not disseminated enough in Yemen, so far, except those using this technology

in rural areas, water resources specialists and some academic circles, epically about the different types of collection systems, storage options, filtration methods, and distribution systems. Thus, stakeholders may not be able to make informed decisions about which technologies are most suitable for their needs as well as can create a perception that the implementation and operation of such systems require specialized knowledge and skills.

Mass media needs to work on this seriously to urge public opinion and decision makers move forward to deep understanding the need of rainwater harvesting technology as additional source of drinking water and for supplementary irrigation.

IV. Technical,

- **Lack of Simply Maintained Purification Filters, Carbon Filters, and Other Parts:** Absence of local manufacturers of simply maintained purification filters, carbon filters, and other parts. Also, water processing chemicals and their containers of steel, fiberglass, and polyethylene. The barrier here is importing procedures of building materials and equipment.

V. Institutional

- **Outdated Strategies and Plans:** Old strategies and plans are one of the institutional barriers that constrain steps or delay the actions towards continuously developing water harvesting technology and technology improvement.
- **The lack of specific policies, regulations, and guidelines** related to rainwater harvesting to develop rainwater harvesting technology to become a profitable business for agrarian and investors can create uncertainty and confusion among individuals and organizations interested in implementing such systems. Without clear guidelines on system design, installation, water quality standards, and maintenance requirements, stakeholders may hesitate to invest in rainwater harvesting projects.
- **Insufficient institutional capacity at the governmental level,** including a lack of dedicated departments or agencies responsible for rainwater harvesting, inadequate staffing, and limited expertise in rainwater harvesting technologies and practices.
- **Lack of coordination mechanisms** for collaboration and coordination among various stakeholders, including government bodies, water utilities, regulatory agencies, and community organizations can impede progress. There are no clear roles, responsibilities, and communication channels that address the multifaceted aspects of rainwater harvesting, such as water rights, water quality standards, and infrastructure development.

4.2.8 Identification of Measures for Rainwater Harvesting Technology

Barriers to rainwater harvesting technology can be overcome through a combination of the following economic and financial measures, and non-financial measures. Table 4-6presents the proposed measures to overcome the economic and financial barriers and Table 4-7 presents the proposed measures to overcome the non-financial barriers.

4.2.8.1 Economic and Financial Measures of Rainwater Harvesting

The measures that mentioned in the table below require collaboration between various stakeholders, including governments, financial institutions, NGOs, and communities. By combining efforts and exploring multiple avenues to address Economic and financial barriers and promote the affordability of rainwater harvesting systems

Table 4-6: The proposed measures corresponding to the economic and financial barriers and expected benefits of rainwater harvesting

#	Economic and Financial Barriers	Proposed Measures	Expected benefits

1	Capital and Installation Cost	▪ Exempting import duties of building materials and other components. ▪ Access the financial resources under climate finance channels to spread the technology deployment for households and agricultural purposes and overcome the installation and construction costs. ▪ Providing incentives for all kinds of rainwater harvesting for households and agriculture purposes from small to large scale	▪ Reduced financial burden on rainwater harvesting projects. ▪ Overcoming high installation and construction costs. ▪ Increased accessibility of rainwater harvesting technology for households and agricultural purposes.
2	High Loan interest and Inadequate subsidy programs	▪ Development of a suitable financial mechanism to support the construction implementation of rainwater harvesting areas in rural areas for agricultural purposes. ▪ Initiate programs by government, NGOs, and development banks to support the construction of rainwater harvesting using low concessional and low-interest loans.	▪ Support for construction of rainwater harvesting systems in rural areas for agricultural purposes.

4.2.8.2 Non-Financial Measures of Water Harvesting

Table 4-7: The proposed non-financial measures corresponding to the non- financial barrier and expected benefits of Rainwater Harvesting

#	Economic and Financial Barriers	Proposed Measures	Expected benefits
1	Lack of training program for future operators and maintenance personnel	▪ Training and capacity-building programs	▪ Ensuring a skilled workforce that can effectively operate and maintain the technology.
2	The absence of the integrated water resources management (IWRM) regulations and plans, that can control and monitor the use of all the available resources for efficient water management	▪ Development and Implementation of IWRM Policies by develop comprehensive IWRM policies that outline principles, goals, and strategies for sustainable and integrated water management. These policies should incorporate legal frameworks, guidelines, and regulations to govern the use, allocation, and conservation of water resources.	▪ Establish a framework for integrated water resources management, promote efficient water use, and ensure the sustainability of water resources for present and future generations.
3	Inactive Quality Control Regulations	▪ Activate the quality control authority and support LWSSCs' laboratories. ▪ Development of IWRM, emphasizes on the efficient utilization of the available water resources, including the rainwater harvesting deployment for agricultural and household purposes.	▪ Ensuring compliance with quality standards for rainwater harvesting systems. ▪ Effective water management and efficient utilization of rainwater harvesting, especially the rainwater harvesting.
4	Inadequate awareness of the Existing Rainwater Harvesting Technology	▪ Disseminate awareness by the traditional and internet mass media, organize lectures, and hold workshops on the technology. ▪ Conduct public awareness campaigns to educate communities,	▪ Increased knowledge and understanding of rainwater harvesting technology. ▪ Educating communities, farmers, and stakeholders about the benefits of water harvesting.

		farmers, and other stakeholders about the benefits of water harvesting. ▪ Raise awareness about water scarcity, climate change impacts, and the role of water harvesting in sustainable water management. ▪ Promote behavioural change and encourage individuals to adopt water harvesting practices at the household level.	▪ Encouraging individuals to adopt water harvesting practices at the household level.
5	Lack of Simply Maintained Purification Filters, Carbon Filters, and Other Parts	▪ Encourage local investors to invest in the manufacturing of simply maintained purification filters, carbon filters, and other parts of the system	▪ Availability and affordability of simply maintained purification filters, carbon filters, and other parts.
6	Outdated Strategies and Plans	▪ Update the existing strategies and plans to include climate change impacts on the water sector and refurbish the ideas about new rainwater harvesting technologies aspects while conducting a comprehensive review and assessment of strategies and plans. ▪ Integrate rainwater harvesting into the climate change plans and strategies, especially, GCF country program NAPs and NDCs	▪ More effective addressing of water sector challenges. ▪ Improved resilience of water management systems to climate change impacts, such as droughts and water scarcity. ▪ Enhanced alignment of water sector strategies with national and international goals for sustainable development and environmental conservation. ▪ Integrating the technology into the national climate change policies and plans will help to access more international support through the climate finance entities. ▪ Increased integration of innovative technologies and best practices in rainwater harvesting, resulting in more efficient and effective water resource management
7	Lack of Institutional and Policy Support.	▪ Institutional support and formulation of policies to regulate and facilitate the development of rainwater harvesting technology business and manufacturing in the country. ▪ Strengthen institutional capacity for water harvesting by: o Develop comprehensive technical guidelines and manuals that provide step-by-step instructions, best practices, and standards for water harvesting systems. o Knowledge sharing and networking o Policy and regulatory frameworks o Establish a coordinating body, to promote the implementation of IWRM including the deployment of rainwater harvesting.	▪ Regulation and facilitation of rainwater harvesting projects. ▪ Enhanced coordination and collaboration among relevant institutions and stakeholders involved in rainwater harvesting projects. ▪ Clear guidelines and regulations for the implementation and maintenance of rainwater harvesting systems, ensuring their effectiveness and longevity. ▪ Streamlined decision-making processes and faster approval of rainwater harvesting initiatives, leading to accelerated implementation and widespread adoption.

		○ Set up formal communication channels to facilitate regular and effective communication among stakeholders.	

4.3 Linkages of Identified Barriers for the Desalination and Rainwater Harvesting Technologies

Desalination and rainwater technologies have many common barriers. Table 4-8 summarizes the linkages of the identified barriers.

Table 4-8: Linkages of Identified Barriers for the Desalination and Rainwater Harvesting Technologies

#	Category	Barriers	Linkage
1	Economic and financial	▪ High initial system cost	▪ High initial cost may not be affordable to users of the two technologies.
		▪ High interest rates on loans	▪ The user also faces difficulty in obtaining loans due to the high interest rates.
		▪ Inadequate of subsidy programs	▪ Lack of subsidies leads to unaffordability of these technologies
2	Non-financial	▪ Lack of capacity building (institutional and technical)	▪ Weak institutional and technical capacities led to not using these two technologies properly.
		▪ Inadequate awareness ▪ Absence of local	▪ Users have little or no information on the techno-economic feasibility of the two technologies.
		▪ manufacturers for identical filters and parts	▪ There is no manufacturing or assembling processes for both technologies
		▪ Old strategies and plans	▪ The old strategies do not put the rainwater harvesting among the most priorities for water resources conservation
		▪ No institutional body to coordinate the investment	▪ No national specialized corporation has been established so far.

4.4 Enabling Framework for Overcoming the Barriers

The enabling approaches to a particular technology are defined by enabling the diffusion process of the technology through overcoming and minimizing the barriers and challenges that hinder its existence, implementation, and utilization on the ground. These include economic and social conditions, availability of resources, laws, supportive policies and regulations, capacity building, and availability of required technology. An enabling framework for overcoming barriers in desalination and rainwater technologies is presented in

Table 4-9: Enabling framework for overcoming barriers for both desalination and rain water harvesting in water sector, also the responsible government authority.

#	Enabling Environment	Measures Needed	Responsible Government Authority
1	High initial system cost	▪ Taking the apparent use of legal statutes to facilitate accessing special funds, donor organizations, and donor countries.	▪ Ministry of Planning and International Cooperation. ▪ Ministry of Agriculture, Irrigation, and Fisheries. ▪ Ministry of Industry and Trade. ▪ Ministry of Water and Environment. ▪ Social Fund for Development. ▪ Public Work Project
		▪ Encouraging the private sector to construct local manufactures.	▪ Ministry of Planning and International Cooperation. ▪ Ministry of Industry and Trade.

2	High-interest rates on loans	▪ The government may guarantee banking loans or cooperate with local banks to reduce interest rate	▪ Ministry of Planning and International Cooperation. ▪ Central Bank
3	Inadequate of subsidy programs	▪ Communicating with different supporting organizations to get more funding	▪ Ministry of Planning and International Cooperation. ▪ Ministry of Agriculture, Irrigation, and Fisheries. ▪ Ministry of Water and Environment. ▪ Social Fund for Development. ▪ Public Work Project
4	Lack and absence of skilled workers	▪ Educational programs for desalination should be provided at the bachelor's level and in occupational training institutions, including desalination and rainwater harvesting, where engineers and technicians must receive adequate hand-on training such as installation, operation and maintenance of the systems.	▪ Ministry of Planning and International Cooperation. ▪ Ministry of Agriculture, Irrigation, and Fisheries. ▪ Ministry of Water and Environment. ▪ Ministry of Technical Education and Vocational Training. ▪ Social Fund for Development. ▪ Public Work Project.
5	Inadequate awareness	▪ Spreading awareness in the society about non-conventional sources of drinking water from schools to universities, in addition to activating the media to explain the advantages of these technologies.	▪ Ministry of Planning and International Cooperation. ▪ Ministry of Agriculture, Irrigation, and Fisheries. ▪ Ministry of Water and Environment. ▪ Ministry of Technical Education and Vocational Training.
6	Absence of local manufacturers of small-scale systems	▪ Establishing factories for technologies' components.	▪ Ministry of Planning and International Cooperation. ▪ Ministry of Agriculture, Irrigation, and Fisheries. ▪ Ministry of Water and Environment. ▪ Ministry of Technical Education and Vocational Training. ▪ Social Fund for Development. ▪ Public Work Project.
7	Inadequate strategies and plans	▪ Update previous strategies and draw new plans	▪ Ministry of Planning and International Cooperation. ▪ Ministry of Agriculture, Irrigation, and Fisheries. ▪ Ministry of Water and Environment. ▪ Ministry of Technical Education and Vocational Training. ▪ Social Fund for Development. ▪ Public work project.
8	Feeble private sectors in the desalination technologies	▪ Offering incentives and formulate and issue institutional supporting laws to contribute the private	▪ Ministry of Planning and International Cooperation. ▪ Ministry of Agriculture, Irrigation, and Fisheries.

	investment, especially the large-scale projects	sector effectively in this technology.	▪ Ministry of Water and Environment. ▪ Ministry of Technical Education and Vocational Training. ▪ Social Fund for Development. ▪ Public Work Project.
9	Non-existence of an institutional body to coordinate the investment mobilization of desalination and rainwater harvesting	▪ Providing the new established institutional body with all possible legal facilities and tools to encourage the investment in these technologies	▪ Ministry of Planning and International Cooperation. ▪ Ministry of Agriculture, Irrigation, and Fisheries. ▪ Ministry of Water and Environment. ▪ Ministry of Technical Education and Vocational Training. ▪ Social Fund for Development ▪ Public Work Project.

. These two technologies must be at the top of priorities in the national plans and policies, especially the National Adaptation Plan (NAP), GCF country program and Nationally Determined Contribution (NDC), and other policies.

Table 4-9: Enabling framework for overcoming barriers for both desalination and rain water harvesting in water sector, also the responsible government authority.

#	Enabling Environment	Measures Needed	Responsible Government Authority
1	High initial system cost	▪ Taking the apparent use of legal statutes to facilitate accessing special funds, donor organizations, and donor countries.	▪ Ministry of Planning and International Cooperation. ▪ Ministry of Agriculture, Irrigation, and Fisheries. ▪ Ministry of Industry and Trade. ▪ Ministry of Water and Environment. ▪ Social Fund for Development. ▪ Public Work Project
		▪ Encouraging the private sector to construct local manufactures.	▪ Ministry of Planning and International Cooperation. ▪ Ministry of Industry and Trade.
2	High-interest rates on loans	▪ The government may guarantee banking loans or cooperate with local banks to reduce interest rate	▪ Ministry of Planning and International Cooperation. ▪ Central Bank
3	Inadequate of subsidy programs	▪ Communicating with different supporting organizations to get more funding	▪ Ministry of Planning and International Cooperation. ▪ Ministry of Agriculture, Irrigation, and Fisheries. ▪ Ministry of Water and Environment. ▪ Social Fund for Development. ▪ Public Work Project
4	Lack and absence of skilled workers	▪ Educational programs for desalination should be provided at the bachelor's level and in occupational training institutions, including desalination and rainwater harvesting, where engineers and technicians must receive adequate hand-on training	▪ Ministry of Planning and International Cooperation. ▪ Ministry of Agriculture, Irrigation, and Fisheries. ▪ Ministry of Water and Environment. ▪ Ministry of Technical Education and Vocational Training. ▪ Social Fund for Development. ▪ Public Work Project.

		such as installation, operation and maintenance of the systems.	
5	Inadequate awareness	▪ Spreading awareness in the society about non-conventional sources of drinking water from schools to universities, in addition to activating the media to explain the advantages of these technologies.	▪ Ministry of Planning and International Cooperation. ▪ Ministry of Agriculture, Irrigation, and Fisheries. ▪ Ministry of Water and Environment. ▪ Ministry of Technical Education and Vocational Training.
6	Absence of local manufacturers of small-scale systems	▪ Establishing factories for technologies' components.	▪ Ministry of Planning and International Cooperation. ▪ Ministry of Agriculture, Irrigation, and Fisheries. ▪ Ministry of Water and Environment. ▪ Ministry of Technical Education and Vocational Training. ▪ Social Fund for Development. ▪ Public Work Project.
7	Inadequate strategies and plans	▪ Update previous strategies and draw new plans	▪ Ministry of Planning and International Cooperation. ▪ Ministry of Agriculture, Irrigation, and Fisheries. ▪ Ministry of Water and Environment. ▪ Ministry of Technical Education and Vocational Training. ▪ Social Fund for Development. ▪ Public work project.
8	Feeble private sectors in the desalination technologies investment, especially the large-scale projects	▪ Offering incentives and formulate and issue institutional supporting laws to contribute the private sector effectively in this technology.	▪ Ministry of Planning and International Cooperation. ▪ Ministry of Agriculture, Irrigation, and Fisheries. ▪ Ministry of Water and Environment. ▪ Ministry of Technical Education and Vocational Training. ▪ Social Fund for Development. ▪ Public Work Project.
9	Non-existence of an institutional body to coordinate the investment mobilization of desalination and rainwater harvesting	▪ Providing the new established institutional body with all possible legal facilities and tools to encourage the investment in these technologies	▪ Ministry of Planning and International Cooperation. ▪ Ministry of Agriculture, Irrigation, and Fisheries. ▪ Ministry of Water and Environment. ▪ Ministry of Technical Education and Vocational Training. ▪ Social Fund for Development ▪ Public Work Project.

Expected outcomes and overall impacts:

Desalination and rainwater harvesting are two approaches used to address water scarcity and ensure water availability in regions with limited freshwater resources. The expected outcomes and overall impacts of implementing these technologies are as follows:

- **Increased water availability and security:** The integration of desalination and rainwater harvesting technologies enhances water availability by providing a reliable and diversified water supply. Desalination converts seawater or brackish water into potable water, while rainwater harvesting captures and stores rainwater for various uses.
- **Climate change adaptation and resilience:** The utilization of both desalination and rainwater harvesting technologies helps communities adapt to climate change impacts on water resources. By reducing dependence on traditional freshwater sources and diversifying water supplies, these technologies enhance resilience in the face of changing precipitation patterns and droughts.
- **Economic opportunities and cost savings:** The implementation of desalination and rainwater harvesting projects stimulates economic growth and job creation. It creates employment opportunities in construction, operation, and maintenance, supporting local economies. Furthermore, rainwater harvesting can lead to cost savings by offsetting the use of treated water for non-potable purposes and reducing the need for infrastructure investments.
- **Enhanced community resilience and self-sufficiency:** The use of desalination and rainwater harvesting technologies empowers communities to become more resilient and self-sufficient in water management. It reduces reliance on external water sources, enhances water security, and encourages active community participation in sustainable water practices.

Agriculture Sector

5. Agriculture sector:

5.1 Preliminary Targets for Transfer and Diffusion for Technologies

The Agricultural sector faces many challenges including high levels of poverty, rapid population growth, poor social and economic infrastructure, and the extremely fragile and limited natural resources base that limit productivity. The cultivated area is decreasing due to many factors like the use of traditional farming practices, poor management of land and other resources, low yield of crops, scarcity of water, limited and uncontrolled use of agricultural inputs, and its high price, and migration of the workforce to cities or abroad. On the other hand, the population increase and increase in their economic activities lead to more pressure on the already stressed and dwindling natural resources. All these factors lead to the expansion of poverty and malnutrition (MAI, 2013), and an exacerbating competition for resources occurs causing social and political instability.

Agriculture in Yemen highly depends on being rainfed. In 2013, the total area was 1.6m.ha. cereals and legumes occupied 60%. The rainfed agriculture covers roughly 66% of the total cultivated land mass. About 27% area of the total cultivated land is mainly irrigated from groundwater sources (MoPIC, 2013)[3] and to a lesser extent (about 7% of agricultural land) from other sources like Gails (water streams), dams, and reservoirs. However, the total arable land could reach approximately 2.5 m.ha (Muharram & Alsharjabi, 2019). Approximately 84% of Yemen's water is used for agriculture – 30 percent of which is used for qat(UNDP, 2022) .

The Government of Yemen launched the Poverty Reduction Strategy (PRS) (2003-2005) to reduce the poverty level. The National Water Sector Strategy and Investment Program (NWSSIP), 2004 focused on efficient agricultural water use. The main feature of the National Agriculture Sector Strategy (NASS) adopted by the Government of Yemen in 2012 was to address and to tackle the major identified challenges of the Yemeni agriculture sector, to combat climate change impacts on the agricultural sector, and to achieve food security, increase smallholder agricultural productivity, and build resilience. Yemen has also framed regulations to preserve the genetic material of healthy varieties and their seeds, and maintenance to rehabilitate dwindling agriculture.

Agricultural Research & Extension Authority (AREA) addresses the issues of the agricultural sector (both plants and animals) through planning, implementing, and evaluating scientific and applied research and studies via various research programs and activities to provide solutions that would ensure; higher quality and quantity production, productivity, better income and living conditions for producers under all country's agro-ecological zones. AREA continues to produce and disseminate farm technologies such as new varieties of main crops and only some of these varieties are reproduced by the general incorporation of seed multiplication (GISM), and made available to farmers. AREA and the National Extension Service (NES) contribute to the dissemination and transfer of modern and improved farm technologies to various groups of users including farmers and other rural producers.

Table 5-1: Technologies and Preliminary target for prioritized technologies (drip, terraces)

#	Prioritized technology	Preliminary target

[3] Ministry of Planning and International Cooperation (MoPIC) (2013). Statistical yearbook for the year 2012. Sana'a, Yemen.

1	Drip irrigation	The aim is to expand drip irrigation across all 22 governorates of Yemen, targeting smallholder farmers, especially those with solar-powered water pumps, and key crops such as coffee in four governorates (Mahwit, Taiz, Abyan and Lahj). Four pilot sites in each governorate will cover 12 hectares, or 48 hectares per governorate per year, with a target area of 1,152 hectares over six years (2025-2030) in four governorates. The programme will build on successful drip irrigation projects and gradually expand, including farmer training, and will be implemented with key stakeholders, particularly the Ministry of Agriculture. The program can be combined with terrace technology as coffee production is concentrated in terraced areas at altitudes of 100-2,500 metres above sea level.
2	Terraces	A 6-year (2025-2030) terrace maintenance program will focus on conserving 662,000 hectares of terraces across the southern highlands (Taiz, Aldhale, Lahej, and Abyan), targeting small farmers and crops like sorghum, wheat, barley, and coffee. According to a case study conducted by ARERA, the rate of deterioration in terraces ranges between 5-14%, meaning an approximate average of 10%, so there is an opportunity to conserve approximately 66,200 hectares (Muharram & Alsharjabi, 2019). This can be done through a 6 years terrace maintenance program with a focus on small farmers and crops of sorghum, wheat and barley, in addition to cash crops such as coffee. On the other hand, there is still the possibility of adding new stands. Each year, the program will build new terraces for coffee conservation on 1,200 hectares, benefiting 1,200 farmers. The long-term goal is to create terraces on 7,200 hectares over 6years.

Traditional agricultural practices still dominate the agricultural sector, represented by a large number of terraces, old dams, and irrigation channels. The new technologies such as high-efficiency drip irrigation have been highlighted as an important technology in second and third national communication. The use of solar energy for groundwater extraction opens opportunities for farmers but needs to be regulated to avoid over-pumping.

The agricultural sector was ranked as one of the key vulnerable sectors to the impacts of climate change. For these reasons, the sector was ranked and selected among the top priority sectors within the first phase of the TNA. During stage I of TNA (the prioritization process), a set of technologies was identified, screened, and ranked, resulting in the selection of the following four priority technologies:

1. Water harvesting and storage technology for agricultural purposes.
2. Irrigation saving techniques.
3. Agriculture soil management and conservation.
4. Reuse of treated wastewater and greywater.

For phase II, it was found to be difficult to analyse the barriers and identify measures for the four ranked technologies for the sector. Therefore, another round of prioritization process was needed. For this purpose, out of the top four selected technologies for the sector in Phase 1, two technologies have been chosen for the second phase (BA&EF). To select the most two important technologies, the four options were examined against a specific selection criterion including Necessity of the technology, Level of the barriers, Paradigm-shifting, and climate potential through a Multi-Criteria Analysis (MCA) exercise, using a scoring system of 1 to 5, with 1 being "low important" and 5 being "very high important.".

The two selected technologies resulted from his exercise are:

1) Irrigation saving techniques (Drip irrigation), and
2) Agriculture soil management and conservation (Terraces).

The above-mentioned technologies in the agriculture sector are mainly prioritized as an adaptation measure to reduce the vulnerability of the population linked with or dependent on the agriculture sector to the impact of climate change. However, it is emphasized from the outset that the above two technologies are available and used in Yemen at various

levels, and the only issue is that these technologies are not being used and implemented widely in efficient manner enough to bring sustainable benefits to the agriculture sector.
The preliminary targets identified under the TNA project for the transfer and diffusion of these technologies in the agriculture sector are:

- Installation of drip/sprinkler irrigation system of agriculture farmlands in the targeted areas.
- To provide training to farmers on efficient irrigation techniques and water management.
- To re-habitation the agricultural terraces.
- Strengthening the capacity of the local farmers on soil conservation.
- Installation of suitable technologies for trace tillage.
- Increases agriculture productivity.
- Prevents soil degradation.
- Reduces chemical application in crop production.
- Efficient use of water resources.
- Disseminates modern farm practices to improve the quality, quantity and reduced cost of production.
- Changes the socio-economic status of farmers.

5.2 Barrier Analysis and Possible Enabling Measures of Irrigation Saving Techniques (Drip Irrigation)

After the second round of prioritizing technologies through Multi-Criteria Analysis (MCA), the discussion with the stakeholders focused on identifying the barriers, measures, and enabling environment. Potential barriers were identified through participatory workshops, discussion with experts in the field, distribution of a survey "questionnaire" to the main players in the sector, and a literature review related to the subject. More explanation of the methodology is discussed in section two of this report.

5.2.1 General Description of Irrigation Saving Techniques (Drip Irrigation)

Despite years of national conflict, government instability, and unregulated agriculture activities, Yemen has the potential to shift to sustainable agriculture and wise water use practices. Through efficient irrigation, water use can be reduced to sustainable levels, lowering the cost of production and increasing the availability of domestically grown food crops. Irrigation is necessary for farming in Yemen due to the arid climate; however, the current methods of irrigation are not sustainable. In 2004, only 0.1% of agricultural land was irrigated through modern localized irrigation methods. In addressing the growing demand for scarce water resources, modern irrigation technologies have shown positive effects on yield, income, and food security. Further, fertilizers and agricultural chemicals can also be applied more efficiently through these irrigation technologies. The irrigation-saving techniques application is simple and suitable for different types and sizes of farms, it has a low investment cost, has proven its successfulness in efficiently reducing the amount of water for irrigation and hence conserving water resources, provides point sources of irrigation water which improve crop production, and eventually help farmers to adapt to climate change and negative impacts on agriculture.

Irrigation technologies and operation can be classified into gravity–fed–surface (flood and furrow) and pressurized (sprinkler and drip) systems. Components of gravity-fed systems are water sources and storage and channels or pipes to distribute water to the field. Localized irrigation or micro-irrigation involves pumping and distributing the water via a low-pressure piping system, bringing the water near cultivated plants only. This is the most efficient irrigation method today. The high-efficiency irrigation systems including drip and sprinkler irrigation techniques are the best-known water-saving technologies for irrigation purposes.

There are four main types of drip irrigation: soaker hoses (also sometimes known as porous soaker lines), emitter systems, drip tapes, and micro-misting systems. Each system has different features and benefits depending on farmers'

needs. The drip emitter irrigation system is by far the most efficient and widespread in Yemen. It typically uses less water, and the water it does use is less prone to evaporate. It is an ideal way to water clay soils because the water is applied slowly, allowing the soil to absorb the water and avoid runoff, easy to use fertilizers, can be used for large areas, and is less labour intensive. In addition, drip irrigation significantly reduces erosion in fields and nutrient loss in soil, two problems that afflict the arable land in Yemen.

Drip irrigation is a method in which water is supplied to crops at a "specific point" usually at the base of the plant. This method uses a network of pipes ending with small emitters to give water to the plant roots. Drip is used best for a wide range of vegetables and crops. Farmers in many countries saw a decrease in water use of 30 to 60 percent when they switched to drip irrigation. In the agriculture sector, irrigation is the key aspect to the development of the sector, and the effectiveness of the irrigation system is highly compromised because of high water losses due to surface irrigation at the different steps of conveyance through the water channels, streams, and fields. Drip irrigation was introduced in Yemen in 1976 by the Agricultural Research and Extension Authority (AREA). To this end, it is obvious that drip irrigation is a method of localized irrigation saving techniques that could increase irrigation efficiency in Yemen.

Installation of this technology requires:

- Pumps or pressurized water systems which take water from the source and provide pressure for delivery into pipe systems. Pressure varies from 2-3 bars to more than 10 bars.
- Filtration system.
- Pipes (including main pipeline and tubes);
- Control valves and safety valves.
- Drip emitters or mini-sprinklers and their variances.
- Monitoring plant water needs through tensiometer or through programs addressing irrigation quantity and frequency provided by technicians.

The technology adaptation benefits:

Based on climate forecasts and the reality of fluctuations in rainfall rates in Yemen and many countries in the region which projected decline in rainfall and freshwater availability, High-Efficiency Irrigation System (HEIS) technology provides efficient use of water supply especially in arid and semi-arid drought-prone areas or those with seasonal rainfall. It reduces the demand for water by reducing water evaporation losses.

5.2.2 Identification of Barriers of Irrigation Saving Techniques (Drip Irrigation)

In order to identify barriers for the technology of drip irrigation, several steps were undertaken, including review of related literature and relevant policy papers, consultation meetings and workshops with the relevant stakeholders from the government institutions, consultants, experts, CSO, NGO, private sector etc. and field surveys were designed and used to collect information.

Several barriers were identified during this process; however, the general main barriers are the ongoing conflict and political instability which weaken the country's economy, local incomes, institutional arrangements and hindered laws, strategies, and legislation updating and enforcement. also resulted in poor water infrastructure, water scarcity, and poor water quality.

Due to the low local income of farmers, the system wasn't widespread, the main socio-economic challenges include the high cost of modern irrigation systems, inadequate credit facilities, and market inaccessibility. Other barriers related to the technology are on how to use and maintain drip irrigation systems. So, the success of implementing new irrigation systems will depend largely on the motivation and the level of awareness of farmers.

The identified barriers have been categorized into the following:

5.2.2.1 Economic and Financial Barriers of Drip Irrigation System

Table 5-2: The proposed barriers corresponding to the economic and financial category of drip irrigation system.

#	Category	Barriers
1	Economic and Financial	▪ High capital, installation, and maintenance cost per unit area ▪ Lack of a stimulating investment environment

i. High capital, installation, and maintenance cost per unit area

The capital cost, installation and maintenance of drip irrigation equipment and lack of technical support for end-users are some of the major challenges being faced by the farmers. The high price is closely linked to the type of crop; perennial tree crops, such as fruit trees, can have a drip system installed on an ongoing basis, so labour and maintenance costs are lower, while seasonal and fast-growing crops have higher labour and maintenance costs because they need to install and remove a drip irrigation network with each agricultural season, in order to plough the land for the new crops. The field characteristics contribute to the high cost per unit area. Flat lands are easier to deal with than lands of varying heights. The most important factor in the high costs of drip irrigation is the energy source, whether to pump water from the wells or to pump water through the drip network. The estimated cost of a drip irrigation unit for an area of one hectare amounts to about 2,000 US dollars, as the unit includes the main and subsidiary pumping pipes, emitters, filters, connections and other accompanying tools, not counting the pump, which may reach 5,000 US dollars and more. The price also varies according to the type of crops, according to the agricultural system, whether it is open or greenhouse, and according to the geographical location. Furthermore, the unstable situation also leads to currency fluctuation and price instability, which constitutes barriers for traders as a result of the instability of the hard currency price to import materials and goods, and barriers for beneficiaries (farmers), as prices increase significantly overtime which makes prices of the high-quality materials unreachable by the majority of people. In a study by Musaed Aklan and Helen Hackner, 2021, the cost of the solar irrigation system in Hadhramaut was estimated at between 10,000 and 17,000 US dollars (Baldauf & Aklan, 2023).

ii. Lack of A Stimulating Investment Environment

Although adopting irrigation technologies has a high return on investment, there is no stimulating environment for investment because there are no government programs that encourage farmers and the private sector to invest in these technologies. This also includes weak law enforcement, which leads to the entry of many poor-quality goods, in addition to weak technical support and lack of experience in using technology, which also leads to loss or breakdown of the irrigation system. Other factors weaken investment in the field of drip irrigation, including the availability of a water source, it has been noticed that farmers who have a cheap water source have less desire to invest in drip irrigation, and this changes in the event of a water shortage or cases of drought, as they begin to search for modern technologies to save water.

5.2.2.2 Non-Financial Barriers of Drip Irrigation System

Table 5-3: The proposed barriers corresponding to the non-financial category of drip irrigation system.

#	Category	Barriers
1	Legal and Regulatory	▪ Absence of adequate quality standards and specifications. ▪ Lack of policies, strategies, and regulations.
2	Institutional and Organizational	▪ Lack of coordination mechanism between all concerned parties including government institutions, private sector, service providers, and the end users.
3	Awareness and Knowledge	▪ Low community awareness and knowledge of the technology
4	Technical Issues	▪ Lack of technical information and data about this technology ▪ Limited technical capabilities and skills to maintain the systems.

i. Legal and Regulatory:

- **Absence of Adequate Quality Standards and Specifications:** One of the key barriers and challenges for the technology is the absence of standards and specifications due to the lack of regulations and by-laws which in turn influence the operation and lifespan of these systems. For these reasons, traders and service providers intend to import low-quality materials. In addition, the absence of standards and specifications together with the low economic situation of most of the population helped to influx of low-quality materials into the market. Due to this situation, the relevant institutions do not have the means to check, test, and inspect the quality of imported technology materials.
- **Lack of Policies, Strategies, and Regulations:** It is obvious that the most important component of the drip irrigation system is the water source and the process of pumping water from the source to the drip irrigation network. Therefore, the lack of policies and regulations related to energy for instance represents an important barrier and challenge for the application and spread of technology. The lack of a clear renewable energy policy has led to inappropriate trends of using renewable energy (ex; solar energy) leading to unsustainable and uncontrolled pumping of groundwater. This situation has created a wrong understanding among farmers about water availability for irrigation, as they believe that no need for such water-saving technologies. On the other hand, the lack of regulations to control ways of irrigation, types of crops to be cultivated, and regulating the amount of water used for irrigation have contributed to uncontrolled and bad irrigation practices and hindered understanding of the importance of drip irrigation technology for saving water and improvement of crop production.

ii. Institutional and Organizational:

- **Lack of Coordination Mechanism Between all Concerned parties (Government Institutions, Private Sector as the Service Providers, and the Users):** There are multiple players and partners with the drip irrigation systems, these include government institutions such as the Ministry of Agriculture and Irrigation, The Ministry of Water and Environment, National Water Resources Authority, Environment Protection Authority, Customs Authority, private sector including merchants, suppliers, traders etc., and end users including farmers, local associations, and landowners. Between all these groups, there is a very weak coordination mechanism and quite limited communication channels which create challenges to spread the technology widely in the country. Under such situation, the end users of the technology usually face difficulties to understand and to build confidence on utilization of the technology and to get the require guidance whenever they need.
- **Awareness and Knowledge:** Low community awareness and knowledge on the technology: Awareness and knowledge are essential to the success and spread of any technology. Farmers in Yemen, have some awareness of the importance of drip irrigation technology, but there is no sufficient and appropriate awareness system for agriculture related issues, especially with the weakness of agriculture extension services in recent

years. Currently there is no awareness system for the sustainable use of natural resources, integrated pest control, integrated water management, and no other guidelines, ways, and applicable systems to improve knowledge and raise awareness on the conservation of the limited natural resources such as water, and on the appropriate technologies to help achieve that such as drip irrigation.

- **Lack of technical knowledge**: The farmer imitates the other farmer as he buys the irrigation network from the market without knowing the full information about it in terms of the quality of the product and the types suitable for his crop and soil. There is a great weakness in awareness of market prices, quality of products, installation and maintenance, methods of using the technology, its suitability for different crops and soils, and its application at different geographical areas, these lead to the drip irrigation system being ineffective or damaged, leading to additional losses for the farmers.

iii. Technical Issues

- **Lack of Technical Information and Data about This Technology**: The weakness of information regarding drip irrigation is related to several things, including information related to the technology itself, especially the issue of quality, many products in the market with low-quality and without any quality standards. Information related to methods of using the technology, as it was noted that many farmers use drip irrigation in one way for all crops, there is no helpful information in terms of when to irrigate, soil types, the appropriate type of drip for each plant, and the use of fertilizers. Therefore, weak information is linked to weak agricultural extension and the weak role of agricultural offices in providing guidance and directing agricultural operations in the right way. It is also linked to the general awareness of farmers and decision-makers. The other issue related to information is the availability of climate and agricultural information ، data-sharing services, how farmers can obtain it easily, as there is currently no established system that helps farmers avoid floods, droughts, or agricultural pests. Another important point also is the market information and its organization, the weakness of which leads to a great loss for farmers.

i. Limited Technical Capabilities and Skills to Maintain the Systems

Irrigation techniques are constantly evolving. For farmers in Yemen, it depends heavily on transferring technology experience between farmers, but the success of the drip irrigation technique in a specific location and a specific crop does not mean its success in another location with another crop. An example of innovation in drip irrigation technology is the use of sensors to measure soil moisture according to the plant's needs which saves more water. There is also a lot of knowledge related to drip irrigation, of which there is still a significant lack of understanding, whether at the level of technicians or the level of farmers.

Farmers use drip irrigation technology for its success on other farms, but they have no experience in matters related to the new technology, especially maintenance and repair, and they have not obtained prior training. According to M. Bazza (FAO;2001) the measurements of water savings at the farm level showed that they vary from 10 to over 50% depending on factors such as the accuracy of the design and installation of the system, the capacity of the farmer to operate and maintain his system adequately, the soil type, the crop, etc. The result of FAO study shows that lot of capacity building is still needed to allow engineers to design and install these systems appropriately. Moreover, training of farmers on their operation and maintenance, through sound advisory services, is completely lacking (FAO;2001). According to Musaed Aklan and Helen Lackner, 2021, the users of the solar irrigation system in Sana'a and Hadramaut who were interviewed did not receive any training on installation, operation, or maintenance, except for the little information about installation, which they obtained from Marketing companies.

Note: Although women constitute a large percentage of workers in the agricultural field, it is noted that there are not many women in the technical aspect, for example: installing and maintaining a drip irrigation system.

5.2.3 Identified Measures for Drip Irrigation Technology.

Table 5-4 present a list of proposed measures to address and overcome the identified economic and financial barriers, and the non-economic barriers for the drip irrigation technology

5.2.3.1 Economic and Financial Measures of Drip Irrigation System

Table 5-4: The proposed measures corresponding to the economic and financial barriers and expected benefits of drip irrigation system barriers.

#	Economic and Financial Barriers	Proposed Measures	Expected benefits
1	High capital, installation, and maintenance cost per unit area	▪ Encourage microfinance institutions and the private sector to support farmers through white and very low concessional loans. ▪ Facilitate initiatives for local agricultural industries to produce materials locally. ▪ Integrate the technology into the climate finance projects under GCF, GEF, AF, etc.	▪ Increased accessibility to affordable financing options for farmers, leading to higher adoption rates of drip irrigation systems. ▪ Reduced financial burden on farmers, enabling them to invest in more efficient irrigation practices. ▪ Strengthened local supply chains, reducing dependence on imported materials and lowering costs. ▪ Enhanced economic development and job creation within the local agricultural sector. ▪ Reduced logistical challenges and improved availability of drip irrigation materials for farmers. ▪ Increased funding opportunities for the adoption and expansion of drip irrigation systems. ▪ Improved resilience of farming communities to climate variability by promoting water efficiency.
2	Lack of a stimulating investment environment	▪ Develop and adopt regulations to facilitate and simplify customs requirements to reduce taxes on importing, manufacturing, and marketing of materials. ▪ Implement an awareness program on the importance and benefits of the technology among all partners and players, including the importer companies.	▪ Increased competitiveness of the drip irrigation market, stimulating innovation and product diversification. ▪ Increased knowledge and understanding of drip irrigation benefits among farmers, importers, and other stakeholders. ▪ Enhanced collaboration and cooperation among different actors in promoting sustainable agriculture.

5.2.3.2 Non-Financial Measures of Drip Irrigation System

Table 5-5: The proposed measures corresponding to the non- financial measures and expected benefits of drip irrigation system.

#	Economic and Financial Barriers	Proposed Measures	Expected benefits
1	Absence of adequate quality standards and specifications.	▪ Reactivate the role of the Standards and Specifications Authority to ensure enforcement and inspection procedures on imported materials. ▪ Develop manuals and guidelines of the needed standards and specifications to maintain the quality of the importing components as well as the efficiency and effectiveness of the technology implementation.	▪ Improved quality control and assurance of drip irrigation components, ensuring their effectiveness and longevity. ▪ Protection of farmers against substandard or counterfeit products, safeguarding their investments. ▪ Enhanced credibility and trust in the drip irrigation market, promoting its wider adoption. ▪ Improved understanding of best practices in installation, operation, and maintenance of drip irrigation systems. ▪ Increased system reliability and longevity, reducing downtime and repair costs.
2	Lack of policies, strategies, and regulations.	▪ Review and update existing legislation, policies, and strategies related to irrigation, and develop new ones as needed. ▪ Prioritize the technology to be among the selected technologies in the climate change plans and policies, such as NAPs, and NDCs	▪ Alignment of irrigation policies with the latest technological advancements, including drip irrigation. ▪ Improved regulatory framework supporting the expansion and integration of drip irrigation systems. ▪ Enhanced coordination and cooperation among relevant stakeholders in implementing irrigation policies. ▪ Increased recognition of drip irrigation as a climate-smart solution for water conservation and agricultural resilience. ▪ Allocation of resources and incentives for the adoption and promotion of drip irrigation.
3	Lack of coordination mechanism between all concerned parties including government institutions, private sector, service providers, and the end users.	▪ Establish integrated coordination committees from all stakeholders at national and sub-national levels with accessible communication channels. ▪ Enhance the coordination between the Ministry of Water and Environment and the Ministry of Agriculture and Irrigation regarding efficient irrigation and promoting the diffusion of drip irrigation systems.	▪ Improved communication and collaboration among stakeholders, ensuring efficient implementation and operation of drip irrigation systems. ▪ Enhanced knowledge sharing and exchange of best practices among different actors. ▪ Increased synergy and alignment of efforts, leading to more effective and sustainable use of drip irrigation technology.

4	Low community awareness and knowledge of the technology	▪ Design and implement knowledge and awareness Programs on the technology for the farmers and local communities on technology utilization. ▪ Develop and disseminate information materials such as leaflets, brochures, and manuals about the technology feasibility, from economic and environmental prospectives	▪ Increased understanding of the benefits, usage, and proper maintenance of drip irrigation systems among farmers. ▪ Enhanced capacity of farmers to make informed decisions regarding irrigation practices. ▪ Improved acceptance and adoption of drip irrigation technology at the community level.
5	Lack of technical information and data about this technology besides the Limited technical capabilities and skills to maintain the systems.	▪ Establish a platform for data and information sharing within the Agriculture Research and Extension Authority and distribute technical information during extension activities. ▪ Reactivate the role of agricultural extension to include training for the farmers on how to install, operate, and maintain irrigation systems. ▪ Launch programs by NGOs about efficient irrigation, and the benefits of drip irrigation for enhancing agricultural productivity. ▪ Encourage technical and vocational education about efficient irrigation including drip irrigation.	▪ Improved access to up-to-date technical information and data on drip irrigation for researchers, extension workers, and farmers. ▪ Accelerated learning and innovation in the field of drip irrigation, leading to continuous improvement and refinement of practices. ▪ Improved long-term performance and sustainability of drip irrigation systems. ▪ Strengthened collaboration between NGOs, farmers, and other stakeholders in promoting sustainable agriculture. ▪ Enhanced availability of skilled professionals and technicians in the field of drip irrigation. ▪ Increased employment opportunities and career prospects in the irrigation and agricultural sectors.

The proposed measures in the table above to enhance the drip irrigation technology and overcome existing barriers could be described and summarized as follows:

i. Integrated laws and legislation need to be developed, updated, and enforced to help farms to get efficient solutions such as efficient irrigation systems, grey water recycling, crops with low water needs and high economic returns, water pricing and other legislations that help in sustainable water management and proper use.

ii. With the widespread use of drip irrigation and existing of several drip irrigation materials in the market, there is a need for legislations that help regulate the market. Legislations should address the issue of importing low quality materials of technologies and apply standards and ensure availability of spire parts and raw materials for manufacturing. Apply standards on imported materials

iii. The bases for institutional coordination on water issue exist, but it requires effective coordination mechanisms between all relevant parties. to remove barriers for drip irrigation technology.

iv. Generally, the success of any technology depends on the extent to which users understand the technology and the ability to use it efficiently. Therefore, the role of agricultural extension has been and still an important driver for farmers' capacity building and it should be strengthened. In parallel the government should encourage technical and vocational education to secure technicians for the future.

v. Transferring knowledge and lessons learned between technology producers, farmers, practitioners, and other stakeholders need to be organized through a rich and accessible database. Such database should include available technologies in the market, their characteristics, uses, technology providers, maintenance and repair services providers, platform for discussion, lessons learned, prices, studies, forms and procedures by government and legislations related to the technologies. The different partners should set and discuss the objectives of the database, its management and update.

Activating market monitoring is part of strengthening law enforcement. As proposed in the measures list to overcome the barriers, there must be standards for the specifications of materials used in drip irrigation in order to ensure their sustainability. The Yemeni Authority for Standardization Specifications and Quality Control is responsible for setting specifications and monitoring them in ports and in local markets. Therefore, its role must be strengthened and coordinated with other governmental and private sector. Also, staff must be trained to be capable to examine and inspect the quality of materials in the market. Encouraging technical and vocational education is needed to secure technicians in this field. Despite the presence of many agricultural engineers as well as the presence of some agricultural institutes, the level of agricultural extension still weak. This is due to the state's inability to absorb graduates, low salaries of those who are agriculture extension employees, and lack of incentives. To activate the role of agriculture extension, the number of jobs in the field of extension must be increased, especially in agricultural areas, in addition to intensive courses to revitalize former agricultural extension workers and acquaint them with modern knowledge in the agricultural field. Finally, all agriculture extension activities should be associated with awareness raising activities on drip irrigation technology.

5.3 Barrier Analysis and Possible Enabling Measures of Agriculture Soil Management and Conservation (Terraces)

As described above in section 1.1, the agriculture soil management and conservation (terraces) were among the top technologies identified for agriculture sector in TNA phase I, and then it was subject for further selection exercise and examined using the MCA tool in Phase II. It is also worth mentioning that this technology is non-market technology.

5.3.1 General Description of Agriculture Soil Management and Conservation (Terraces)

Yemeni farmers have been familiar with agricultural activities since ancient times and successfully developed several appropriate farming techniques. In this context, it a noticeably large number of terraces, old dams, and irrigation channels prevailing throughout the country. In Yemen, traditional agriculture has been practiced on mountain terraces for centuries, especially in rain-feed highlands. This system has always played an important role in the social stability of the rural population. Since ancient times terrace walls with contour lines have been constructed which accumulate colluvial deposits for agricultural use, and the topography of the mountains gives a shape for the terraces. The terraces are created by, a low stone wall being erected and material is deposited behind the wall; later fine materials (suspended particles) are flushed during rainfall events and accumulate slowly. Terraces are also found at middle and lower altitude wadi courses with low inclination and expanded wadi beds, albeit with fluvial characteristics, but they similarly have been cultivated until modern times with fruit trees, sorghum, and vegetables. The terrace system also includes water distribution channels from the mainstream to the terraces or between terraces, water sharing, and a traditional maintenance system. From a technical point of view terrace cultivation is an advanced farming system for soil and water-spreading, water-harvesting, and utilization of mountainous lands. The terraces are characterized by limited space and ownership and become smaller and the area of owned land decreases with the succession of heirs, generation after generation. Medieval and later agricultural texts, as well as ethnographic data, reveal that Yemeni farmers were quite knowledgeable about the environment, and the traditional farming systems resulted in minimal environmental damage. Indeed, farmers were usually practical conservationists who knew that their livelihood depended on the careful management of local resources.

Agricultural terraces play an important role in climate change adaptation, as they have withstood previous climate changes for thousands of years. Agricultural terraces work to combat drought as they are a very effective system for collecting rainwater from slopes, store water and support the production of agricultural crops adapted to this system.

The terraces also reduce erosion resulting from rainfall, as well as mitigate flash floods by absorbing a large amount of water. This is aided by traditional knowledge in the torrent irrigation system and distributing water between the terraces. On the other hand, agricultural terraces help preserve the soil and form an ecosystem that is able to transform barren rocky areas into productive ecosystems that support many living organisms and are therefore also considered an important factor in preserving biodiversity.

The mountain terraces land is estimated to be 20% - 25% of the arable land. It is noticed that during the last sixty years, Yemen society has faced many social and economic changes and evolution, which negatively affected terrace cultivation. It is worth noting that the absence of regular maintenance is one of the most important factors of terrace abandonment. Increased drought frequency, increased temperatures, and changes in precipitation patterns – lead to degradation of agricultural lands, soils, and terraces, other factors include migration to urban centres and abroad to search for other alternatives for livelihood and the low agricultural productivity and lack of profitability.
Technically traditional terracing refers to a technique of landscaping a piece of sloped land into a series of successively receding flat surfaces or platforms, which resemble steps, for more effective farming. This type of landscaping, therefore, is called terracing. Graduated terrace steps are commonly used to farm on hilly or mountainous terrain.

The selection was due to their benefits which include:
Maintaining and the rehabilitation of agriculture on these neglected and devastating terraces would help increase production in the country. This intervention will also lead to the use of more manpower and focus on the traditional way of agricultural activities, with the introduction of suitable and high-yielding crops.
This type of soil conservation technology has more advantages for the environment and agriculture sector including improvement in ecosystem conservation, conservation of agricultural soil, reduced land degradation, improved livelihoods of farmers' families, harvest rainwater, and enhancement of the adaptive capacity of farmers community to climate changes as ecosystem-based adaptation. Terraced fields decrease erosion and surface runoff retaining soil nutrients. Terraces contributed to an increase in farm productivity, fight against erosion, and as containers or reservoirs for feeding surface water, an important factor for soil cohesion and overall contributed to poverty reduction in Yemen. These benefits can be summarized as follows;

- Enabling the development of larger areas of arable land in rugged terrain.
- Facilitating modern cropping techniques such as mechanization, irrigation, and transportation on sloping land,
- Increasing the moisture content of the soil by retaining a larger quantity of water,
- Capturing run-off soil which can be diverted through irrigation channels at a controlled speed to prevent soil erosion.

Related agriculture practices on terraces include organic fertilizers and compost, provide valuable nutrients (in the form of N, P, K and S, as well as micronutrients) to enrich the soil organic matter content and enhance soil fertility.

5.3.2 Identification of Barriers of Agriculture Soil Management and Conservation (Terraces)

Barriers of this technology also could be categorized into Economic and financial barriers, and non-economic barriers.

5.3.2.1 Economic and Financial Barriers of Terraces

Table 5-6: The proposed barriers corresponding to the economic and financial category for Terraces

#	Category	Barriers
1	Economic and Financial	▪ High capital, construction, and maintenance cost ▪ Weak market demand for this technology ▪ Lack of Financial Support Program

The terrace technology for soil conservation has been practiced by Yemeni farmers for a long time, however this technology hasn’t been introduced to the market.

i. High Capital, Construction, and Maintenance Cost

Ancient terraces relied on hundreds of years of soil collection. Constructing terraces or maintaining existing ones require a lot of capital and effort. The main materials required are stones and soil. The value of constructing terraces is not limited to building the walls of the terrace only, but there is often a need to strengthen the wadi stream by building gabions, improving canals to the agriculture fields, transporting soil, crushing stones from the mountains and transporting them to build the terraces in addition to the cost of manpower and/or machinery. Building support walls requires the use of cement, and sometimes the construction of terraces itself is supported with cement, which enhances their strength, but bring additional financial cost. Building terraces requires intensive labour in construction, transportation, filling soil, etc. Some reference estimated the total capital cost for 35.41 ha (including cost of digging, stones, workmanship) at about USD 290,385 (USD 8,201 per ha)[4].

Terracing is a technology that does not depend on market supply and demand but depends mainly on its necessity to the farmer's livelihood, and to its general benefit in maintaining the agricultural and environmental system. There is a weak desire among the private sector to invest in agricultural terraces because they are not an investment resource from which a return can be obtained. The private sector prefers to invest in fertile flat lands, especially those with sustainable water resources. The maintenance of terraces has a high capital cost and construction of new terraces need more funds and efforts, so investment on large scale terraces need a hug financial support and cooperation between different public and private sector.

ii. Weak Market Demand for the Technology

There is a weak demand in the market for the technology of building terraces - not because it's not needed - but due to its lack of availability in the market as a technology. In communication with some specialists in the agricultural field, they confirmed the possibility of obtaining price offers for building terraces, but you cannot find an advertisement for an agricultural company or institution that provides the service of building terraces. This is due to the prevailing culture that terraces are an agricultural practice and are not framed within the market.

iii. Lack of Financial Support Program

As the construction cost of terraces is high, the low-income farmers can't maintain their terraces especially if the damage is high, so many farmers lose their income from the terraces and search for new income especially moving to cities.

5.3.2.2 Non- Financial Barriers of Terraces

Table 5-7: The proposed barriers corresponding to the non-financial category for Terraces

#	Category	Barriers
1	Legal and Regulatory	• Lack of clear policies and strategies for land preservation and reclamation.
2	Institutional and organizational	• No coordination mechanism between relevant government institutions, the private sector, donors, and local communities. • Weak capacities of relevant government institutions and community-based institutions
3	Human skills and capabilities	• Poverty and leakage of trained and experienced labour due to migration to urban areas
4	Technical issues	• No research and studies on the technology • Limited data and information about the technology
5	Awareness and knowledge	• Lack of awareness on the benefits of the technology
6	Environmental	• Increased drought frequency, and changes in precipitation patterns

[4] https://www.gefieo.org/sites/default/files/documents/projects/tes/3267-terminal-evaluation.pdf

i. Lack of Clear Policies and Strategies for Land Preservation and Reclamation

During the history of Yemen, terraces played a primary role in agriculture especially in highlands. Until now there hasn't been a clear strategy or plan caring for terraces and their maintenance. Islamic law (shari'a) and customary laws (urf') provide the rules by which conflict and cooperation is mediated within or across tribes. Sheikhs play a convening role both in mobilizing the community for collective purposes and serving as community interlocutors, lobbying local and central government for development projects. Sheikhs are nominated by their communities but have to be formally confirmed by the Government.

ii. No Coordination Mechanism Between Relevant Government Institutions, Private Sector, and Donors

Terraces are generally privately owned lands and residents maintain them according to their personal capabilities. In some places, agricultural associations help farmers maintain the terraces, or farmers help each other. Interventions by international organizations is limited and state intervention is almost non-existent. The Ministry of Agriculture is responsible for developing agricultural terraces and helping farmers maintain them. With little activity in building and maintaining terraces by the government, coordination between partners, which include agricultural financing, whether the Cooperative and Agricultural Credit Bank, the Agricultural and Fisheries Investment Promotion Fund, or the private sector, as well as coordination with international organizations regarding terraces, is almost non-existent. Despite some activities of the Social Fund for Development, which is a government institution, in the field of terrace maintenance, its work is within the implementation of projects for international donors and not within a general plan for the state.

iii. Weak Capacities of Relevant Government Institutions

The issue of terrace deterioration is a well-known problem, it appeared in the national communications to UNFCCC, and in the national plan for sustainable management, as well as the biodiversity strategy, which made it clear that the current government's policy also drives terrace loss and this is reflected in its policy of subsidizing import of grain rather than producing it locally, as well as the state's weakness in combating poverty leads to increased cutting of trees and increased soil erosion, as trees are considered an important factor in preserving terraces because they reduce water runoff. There is no clear government department for managing the terraces, so the weakness is clear in state institutions with regard to the management and development of agricultural terraces.

Poverty is generally considered one of the important barriers to development in general and for the technology specifically. The terraces are owned by smallholder and low-income farmers. There are several factors that accelerate the deterioration of the terraces: support for the import of grains so that they were obtained at a cheaper price than the domestic product, the war that exacerbated the level of poverty, and the lack of programs to support the terraces and small farmers, as well as migration to cities or abroad. According to some studies, the beginning of the deterioration of agricultural lands in Yemen began with the oil revolution in the Gulf, which led to the migration of many labour forces abroad. All of these factors, in addition to climate change, have made farmers poorer and have lost the ability to maintain terraces. The other important factor is the population increase leading to the deterioration of the terrace due to shrinking of terraces owned areas as a result of inheritance from parents to children, as well as the expand of residential areas on agricultural lands.

iv. Limited experienced labour

Experience in building terraces has been passed down from generation to generation, but much of this experience has begun to deteriorate as a result of the current generations' lack of interest in terrace cultivation. Therefore, there are many original concepts and experiences associated with terrace farming that are only found with some farmers. There are also no government programs to document this heritage and re-teach it to future generations. There are some community initiatives, but they are within a narrow framework. As mentioned before Immigration abroad led to a shortage of labour and the deterioration of the agricultural heritage.

v. No research and studies on the terraces

The government and the public deal with terraces as an agricultural practice only, and not as an important agricultural technology especially for soil and water conservation. Therefore, there is no systematic research and studies and no accurate description of the technology, its types, and ways to enhance and maintain.

vi. Limited data and information

The information associated with the terraces is traditional knowledge that is passed down from generation to generation, but there is no precise description of this technology so that it can be taught, transmitted and developed. There is no technical information on how to build an agricultural terrace, how much time and effort it requires, as well as the types of terraces and how to create them. Also, no information about soil types, types of terraces, suitable crops to be cultivated. In addition, there is no information about the causes of damage and deterioration of terraces, how to prevent the damage, and what are maintenance operations. Furthermore, there is significant weakness in knowledge of the inherited customs and traditions that govern the distribution of water and the resolution of disputes related to the terraces.

vii. Lack of awareness on the benefits of technology

People passed on the knowledge of terraces from generation to generation. With the increase in urbanization and the neglect of terraced lands, much of the knowledge related to terraces began to diminish. The weak knowledge of terraces and their importance and the weak connection to the land as a source of income led to less interest in terraces and their further deterioration.

viii. Increased drought frequency, and changes in precipitation patterns

Increased drought frequency, and changes in precipitation patterns cause increasing soil erosion and terrace degradation. Moreover, effect on the infrastructure resilient of terraces against the expected flood.

5.3.3 Identification of Measures for Terraces Technology

The proposed measures to overcome technology barriers are also categorized into economic and financial, and non-economic and financial measures, presented in the tables below.

5.3.3.1 Economic and Financial Measures of Terraces

Table 5-8: The proposed measures corresponding to the economic and financial barriers and expected benefits of terraces

#	Economic and Financial Barriers	Proposed Measures	Expected benefits
1	High capital, construction, and maintenance cost and Lack of Financial Support Program	▪ Directing government and donor support programs for soil conservation and terrace rehabilitation, and encouraging investments in terrace conservation ▪ Develop investment policies and legislations that facilitate support and subsidies for small farmers and terraces farming. ▪ Encourage microfinance institutions, NGOs, and the private sector to support the terrace rehabilitation.	▪ Provide financial resources to farmers for the construction and maintenance of terraces, making it more affordable for them. ▪ create a favourable economic environment for small farmers by providing financial incentives and subsidies. ▪ Attract more farmers to engage in terrace farming, leading to increased agricultural production and income generation. ▪ Leverage additional financial resources from various stakeholders, enabling farmers to access loans and financial assistance for terrace rehabilitation. ▪ Enhance the capacity of farmers to invest in terraces, resulting in

			▪ improved land productivity and sustainable farming practices. ▪
2	Weak market demand for this technology	▪ Invest in awareness and knowledge programs on the importance and economic values of this technology to create a safe environment for investment, especially for some traditional crops, such as Yemeni coffee, Yemeni almonds, etc	▪ Increase awareness among farmers and potential investors about the benefits of terrace farming. ▪ Stimulate market demand for terrace-grown crops by highlighting their economic value, leading to increased investment and market opportunities for farmers.

i. Directing Government and Donor Support Programs for Soil Conservation and Terrace Rehabilitation, and Encouraging Investments in Terrace Conservation

Despite the weak country economy, there are several humanitarian and livelihood projects in Yemen of which the government should direct part to soil conservation and terrace rehabilitation. Supporting agriculture in terraces will bring high impacts to the local economy and food security. This intervention will provide livelihoods and create job opportunities for many young people, making them more stable in rural areas and thus relieving pressure on cities. Also, rebuilding the terraces will create agricultural ecosystems that help preserve the soil and its fertility and moisture, in addition to providing habitats to biodiversity and increasing the adaptive capacity of people and ecosystems for climate change impacts such as drought and flooding.

ii. Develop Investment Policies and Legislations That Facilitate Support and Subsidies for Small Farmers and Terraces Farming

Despite the current difficult situation in Yemen, the government can develop policies and legislations through available budget from donors and private sectors to support terrace development programs, which may include soft loans to farmers.

iii. Invest in Awareness and Knowledge Programs on the Importance and Economic Values of the Technology to Create Safe Environment for Investment

Investment in terraces is related to maintaining them or building new ones. Maintenance of the terraces is related to the owner or sharecropper and is therefore governed by prior agreement with the party that carries out the maintenance. Regarding the construction of new terraces, it may be on owned lands. The government can also encourage investment in bare lands. From here, we can talk about providing a suitable environment for investing on bare lands and increasing the area of agricultural terraces. The investment modality, land ownership and management are organized between the government, the investor, and the local residents in the neighbouring areas. So far, there is no clear legislation governing this or experiences to build upon, but the topic could be put for public discussion. Awareness campaign for investors and decision-makers can be launched to support this direction, not only for terraces bare land but also to cover other lands.

5.3.3.2 Non-Financial Measures of Terraces

Table 5-9: The proposed measures corresponding to the non-economic and financial barriers and expected benefits of terraces

#	Barriers	Proposed Measures	Expected benefits
1	Lack of clear policies and strategies for land preservation and reclamation.	▪ Develop tailored policies and plans for preserving and reclaiming agricultural lands, including building and rehabilitation of terraces	▪ Provide a clear regulatory framework and guidelines for land preservation and terrace rehabilitation. ▪ Ensure sustainable land management practices, prevent land degradation, and

			facilitate the systematic restoration of terraces for long-term agricultural productivity.
2	No coordination mechanism between relevant government institutions, the private sector, and local communities.	▪ Establish coordination channels between the local communities, the private sector, and government institutions for terrace rehabilitation.	▪ Foster collaboration and cooperation among stakeholders involved in terrace rehabilitation efforts. ▪ Improve communication, resource sharing, and knowledge exchange, leading to effective planning, implementation, and monitoring of terrace rehabilitation projects.
3	Weak capacities of relevant government and community-based institutions.	▪ Support the Agriculture Research and Extension Authority to provide technical support for communities and local institutions towards terrace building and rehabilitation	▪ Strengthen the technical expertise and capacity of government and community-based institutions in terrace construction and rehabilitation. ▪ Enhance their ability to provide guidance, training, and technical assistance to farmers, resulting in improved terrace construction and maintenance practices.
4	Increased drought frequency, and changes in precipitation patterns	▪ Design and implement climate resilient interventions to reduce soil erosion and terrace degradation, by using Ecosystem-based Adaptation (EbA) solutions to enhance the adaptive capacity against severe draughts and floods. ▪ Enhance the Infrastructure resilient against the expected flood	▪ Mitigate the impact of droughts and extreme weather events on terraces. ▪ EbA solutions, such as afforestation, soil conservation measures, and water management techniques, can enhance the resilience of terraces to climate change, ensuring their long-term sustainability and productivity.
5	Poverty and Leakage of trained and experienced labour due to migration to urban areas.	▪ Create an incentive and subsidized mechanism to attract local people and encourage them to preserve terrace lands.	▪ Provide economic incentives and support systems to retain skilled labour in rural areas. ▪ Motivate local communities to engage in terrace farming, creating employment opportunities and reducing rural-to-urban migration. It can also preserve the traditional knowledge and skills associated with terrace agriculture.
6	No research and studies on the technology	▪ Integrate technology issues into the curricula and establish centres for vocational training on the terrace technology. ▪ Encourage academia and research institutions to develop research and studies on the technology subject.	▪ Enhance the knowledge and skills of students and farmers in terrace technology. ▪ Promote the adoption of innovative practices and techniques related to terraces, leading to improved efficiency and productivity in terrace farming. ▪ Contribute to the development of evidence-based practices, innovations, and solutions for terrace construction, maintenance, and management. ▪ Foster continuous learning and improvement in terrace farming practices.
7	Limited data and information about the technology	▪ Establish a platform for data and information sharing within the Agriculture Research and Extension Authority on the terrace's necessity for Yemen agricultural practices	▪ Facilitate the exchange of information and data related to terrace farming among stakeholders. ▪ Improve access to relevant information, research findings, and best practices, enabling informed decision-making and promoting effective implementation of terrace-related initiatives.

8	Lack of awareness on the benefits of the technology	▪ Conduct targeted educational campaigns to raise awareness about the benefits of technology. ▪ Collaborate with local agricultural organizations, cooperatives, and NGOs to promote the benefits of technology. These partners can play a crucial role in disseminating information, providing technical support, and organizing awareness campaigns at the grassroots level. Leveraging existing networks and community structures can reach a wider audience and ensure sustained engagement.	▪ Have the potential to raise awareness, disseminate knowledge ▪ Provide technical support, and promote the adoption of technology.

i. Develop Tailored Policies and Plans for Preserving and Reclaiming Agricultural Lands

There is a need for a specific national plan/policy to preserve and reclaim agricultural lands. The plan should be focused on strengthening local communities and government institutions to respond to land degradation. The plan should integrate terraces rehabilitation issues and preserve agriculture lands into other national plans such as poverty reduction, biodiversity conservation, climate changes and investment plans. The plan should also include interventions for restoring and safeguarding agro-ecosystems that provides essential service. It is important that the plan has comprehensive awareness to relief the traditional agricultural knowledge and practices, new innovative technologies and enhance academic and vocational capacity building. Such a planning process should be in a participatory way that engages all stakeholders from community level to decision-makers. The plan should be resulted in action plan with clear targets and interventions supported by budget and funds mobilization plan to implement its interventions. Due to limited data the plan should consider data collection and the establishment of a database.

ii. Establish Coordination Channels Between the Local Communities, the Private Sector, Government Institutions, and Donors

There are several ideas for the coordination process in the agricultural sector, especially the issue of agricultural terraces, from famous experiences such as water basin management and water user groups. It is possible to build on that and create groups of terrace users so that the groups are organized under one committee representing the governorate. Then, they can be linked to the Ministry of Agriculture and agricultural associations and institutions interested in agriculture development. The goal of the terrace user group is to develop initial plans and ideas that will help maintain existing terraces, build new terraces, and improve agricultural production in the terraces. There was a pioneering experience in civil cooperation in Yemen, and its focus was largely on building roads, schools and hospitals. Terraces user groups can be started in some pilot locations and their success could be transformed and applied to other areas. To establish such a mechanism, it should be carried out through discussion and consultations with all stakeholders.

Also, the private sector could be engaged in such a coordination process, and can play an important role, especially in helping to maintain stands, spreading awareness, and training. Another role that the private sector can play is investing in creating agricultural terraces in bare areas. The private sector is concerned with profit, so there must be a sound investment environment and clear legislation that guarantee rights. As a first step, it could begin by opening a window

of dialogue on the issue between the private sector and the government together with all stakeholders to come up with a road map and work program that defines the goals and ways in which the private sector can participate in investing in terraces.

iii. Capacitate the Agriculture Research and Extension Authority to Provide Technical Support for Communities and Local Institutions

Agricultural work in general and terraces in particular must be well organized. The important steps are to revive agricultural extension activities, as the authority has a network of agricultural extension workers in all regions of the country. Therefore, there must be a program to reactivate them and add a new cadre of graduates, in addition to providing them with modern information and intensifying training courses that help them provide useful and modern agricultural extension. It is also necessary to revitalize the sectors related to land use planning, as well as integrated water management, integrated pest control, and other programs that were suspended due to the war or the lack of operational budgets. There is no special department for the management of agricultural terraces, and according to specialists, the management of terraces falls within the management of forests and combating desertification, and some of its programs are implemented under the programs of preserving soil conservation and within watershed management department. Therefore, to reduce interference between departments regarding agricultural terraces, a special department for agricultural terraces could be established or a permanent program for agricultural terrace management could be established under the relevant department. It is also important to create a training plan for all stakeholders including agricultural associations and farmers.

iv. Design and Implement Climate Adaptation Interventions to Reduce Soil Erosion and Terraces Degradation

The terraces systems are deteriorated and degraded significantly due to the consequences of climate change events. Increased drought frequency and occurrence of prolonged drought, and changes in rainfall patterns which occur in short-lived rainstorms leading to flash floods cause significant damage to terrace and soil erosion. It is, therefore, vital and of high importance to design and implement interventions to held building adaptation capacities and enhance resilience of terrace systems.

v. Create an Incentive and Subsidized Mechanism to Attract Local People and to Encourage Them to Preserve Terrace Lands

For several reasons including the ongoing conflict and unstable situation, Yemeni people have been suffering from the deterioration of life status to a very low living standards and are struggling to secure the basic needs with continuous increased level of poverty, less income opportunities, and lose of livelihoods specially the rural farmer communities. As a result, many of the young people and skilled workers are forced to migrate to urban centres to search for better life and income opportunities. This situation has led to abandoned of terraces in many cases as the normal work in terraces is usually depends on the collective work of family members. For this reason, it is recommended to explore for a mechanism that provide more opportunities for income diversification and facilitate the creation of subsidized and incentives system that attract local people to return to their villages and preserve terrace systems.

vi. Integrate Technology Issues into the Curricula and Establish Centres for Vocational Training on the Terrace Technology and Encourage Academia and Research Institutions to Develop Research and Studies on the Technology Subject

The terrace technology - as mentioned previously - has been practiced for centuries in Yemen and farmer community have managed to sustain it generation after generation, so, it has been considered a farmers traditional practice that does not need to be modernized or improved. For that reason, perhaps, there has been no interest from the education and academic community to get exposed to such technology. Although, agriculture extension activates focused - to some extent – on soil preservation which include terrace rehabilitation, but no systematic research, studies, and assessments been conducted to explore the details of the technology. Despite the interest of some studies in the

importance of agricultural terraces, there is no clear studies or economic evaluation on the importance of the direct impact on soil or water conservation.

For these reasons, schools, universities, and research centres need to include technology issued in the curricula and vocational training programs, and researchers are encouraged to carry out research studies, produce training materials on different technology-related issues. These may include types of terraces, their shapes, type of soil, construction, maintenance, materials, stones, labour, prices, transportation, crops, environmental benefits, terrace management, stakeholders, legislations, traditions, conflicts, etc.

Terrace research should receive great attention from researchers, as well as the government and international organizations, because it was and still the backbone of agriculture in Yemen and still represents an opportunity for food security.

vii. Establish a Platform for Data and Information Sharing within the Agriculture Research and Extension Authority

Providing and disseminating data and information about this technology is needed including all data gathered from previous studies to be organized in accessible database. The database should be managed to provide a service for public especially farmers on the agriculture knowledge and extensions. Technical data need to be simplified and summarized to be distributed to farmers during extension activities.

viii. Develop and Disseminate Information Materials such as Leaflets, Brochures, and Manuals

Terraces are a well-known system in Yemen and many customs, traditions and practices are associated with this system. However, with the increase in migration, especially to cities, the stock of knowledge associated with terraces has deteriorated significantly. There is an urgent need to create communication and awareness programs, starting with decision makers, of the importance of this technology, not only of its importance to the agricultural sector, but of its importance to the mountainous ecosystems and their sustainability. Environmental awareness programs that include demonstration fields, along with supporting and reviving agricultural extension are needed in all regions and should involve all stakeholders.

5.4 Linkages of the Barriers Identified (Drip Irrigation and Terraces)

it could be noticed that the two identified technologies for the agriculture sector, namely drip irrigation and terracing as a soil conservation technique, are to a high extent linked to each other and complement each other in terms of the benefits that could be obtained from the application of the technologies. Similarly, the identified economic and financial, institutional, coordination, data and information, the limited capacities, lack of knowledge and low awareness barriers for each technology have the same nature and effects on the spread of the technology's country wide.

Interlinkages between the barriers of both technologies are summarized as follows:

- The high initial as well as maintenance cost associated with no adequate funding is a key barrier for both technologies, which required financial support to be mobilized and provided to the farmers community through grants or very concessional loans. Also, incentives and subsidized support mechanisms, and legislations related to taxes reduction and exemption are to be adopted for both technologies.
- The issue of monitoring, inspection, and testing of imported materials as well as materials produced locally require standards and specifications to be in place. Not only that, but skilled and trained people, equipment, manuals, methodologies, and institutional capacities and procedures are needed to apply them. While such an integrated system is not in place, improvement in applying of these technologies may not be possible.
- The absence of coordination between partners for both technologies including government institutions, beneficiaries from the local communities, private sector, academic and research institutions, community-based organizations etc. is one of the key barriers negatively affecting the diffusion of the technologies.
- The limited skills and technical capacities to install, construct, and maintain the technologies is another main obstacle for the expansion of the technologies countrywide.

- The lack of adequate national policies, plans, and regulations are considered barriers and driving forces that could hinder the expansion of these technologies.
- The systematic research, studies and specific training Programs on both technology issues are important to encourage the application and expansion of the technologies. With the limitation of such educational Programs, the two technologies will continue facing challenges to be developed and diffused.
- The lack of awareness and knowledge among all stakeholders at different levels affect diminish understanding and minimize the knowledge about the advantages, modalities, benefits, requirements, costs, and all related details of the technologies.
- All these interlinked limitations and barriers create layers of collective effects to hider the development, deploy, and diffusion of the two technologies.

5.5 Enabling Framework for Overcoming the Barriers

Although overcoming obstacles begins with peace-making and political stability, there are many measures that the government can take to create an enabling environment that helps the tow technologies developed and spread countrywide. The following points summarize the most important of these enabling steps:

i. Innovative policy that enables the government to direct and utilize international funds for supporting agriculture technologies. With quite a large amount of funds flowing to humanitarian and development in Yemen, the government should create a policy that helps the government to direct these funds to agriculture technologies such as the rehabilitation of terraces and support farmers with drip irrigation systems.
ii. Encouraging and supporting agricultural technologies by integrating them into national legislations strategies and policies.
iii. To overcome the economic and financial barriers, the government has to adopt a package of measures including the development of investment policies and legislations that facilitate financial support for farmers and to reduce taxes on imported materials as well as locally manufactured ones, creating an incentive and subsidized mechanism, engagement of private sector to invest in technologies.
iv. Strengthening the technical capacities of national governmental and community-based associations to be able to apply and maintain the technologies.
v. The government and education community need to support integration of the technologies issues into education system and curricula, training, research Programs.
vi. The need to create coordination and awareness programs/platform to include all partners including government, private sector, local communities, donors, academia, NGOs, and CSOs etc. and establishment of database for data and information sharing.
vii. The private sector is important in the process of supporting agricultural technologies. Therefore, the government must work to open a window of work and discussion with the private sector to develop agricultural technologies and provide them in the local market with specifications appropriate to the natural environment in Yemen and at prices suitable for farmers.
viii. Activating agricultural support mechanisms represented by microfinance institutions while paying attention to small farmers and supporting them with agricultural techniques through easy financial system.
ix. Integration of these technologies into the priorities identified in the national and sectoral policies, such as NAP, NDC, and sectoral polices and plans of the agriculture sector

Table 5-10: Enabling framework for overcoming barriers for both Drip Irrigation and Terraces in agriculture sector, also the responsible government authority.

#	Enabling Environment	Measures Needed	Responsible Government Authority
1	High capital, construction, and maintenance cost for technologies	• Innovative policy that enables the government to direct and utilize international funds for	• Ministry of planning and International Cooperation • Ministry of Agriculture, Irrigation and Fishery

		supporting agriculture technologies	
2	Lack of policies, strategies, and regulations.	• Integrating technologies into national legislations strategies, policies and plans, including NDC and NA	• Ministry of Agriculture, Irrigation and Fishery • Ministry of water and environment
3	Lack of a stimulating investment environment	• Development of investment policies	• General Investment Authority
4	Weak capacity for farmers and government institutions	• Establish technical and institutional program	• Ministry of Water and Environment. • Ministry of Agriculture, Irrigation and Fishery
5	Limited researches and data	• Integrating technologies issues to general and postgraduate study and support researches	• Ministry of Education. • Ministry of Higher Education and Scientific Research.
6	Lack of Awareness	• Establish technologies awareness program	• Ministry of Water and Environment. • Ministry of Agriculture, Irrigation and Fishery Agriculture Research and Extension Authority
7	Lack of coordination mechanism (ex. Private sector)	• Develop discussion platform with private sector	• Ministry of Water and Environment. • Ministry of Agriculture, Irrigation and Fishery Chambers of Commerce
8	High technologies cost	• Strengthening microfinance	• Ministry of Agriculture, Irrigation and Fishery. • Agricultural and fisheries production • Promotion fund • Cooperative & agricultural credit bank. • Al-Amal Bank

Expected outcomes and overall impacts:

In summary, the implementation of drip irrigation and terrace systems in Yemen can contribute to the overall development and resilience of the agricultural sector in Yemen. These practices offer sustainable solutions for sustainable agriculture, ensuring the long-term food security and well-being of Yemeni communities. The expected outcomes and overall impacts are:

- **Improved climate change resilience:** The adoption of drip irrigation and terraces enhances the resilience of agricultural systems to climate change impacts. Drip irrigation reduces the vulnerability of crops to drought and water stress, while terraces mitigate soil erosion and provide water infiltration, ensuring water availability during changing climatic conditions.

- **Increased agricultural productivity and food security:** The integration of drip irrigation and terraces improves water management, nutrient distribution, and soil conservation, resulting in increased agricultural productivity. This enhances food security by ensuring reliable crop yields even in the face of climate variability.

- **Water resource management and conservation:** Both drip irrigation and terraces contribute to efficient water use and conservation. Drip irrigation minimizes water wastage through targeted delivery to plant roots, and terraces enhance water infiltration, reducing surface runoff and optimizing water availability for crops.

- **Soil conservation and erosion control:** Terraces play a crucial role in preventing soil erosion by reducing the flow of water down slopes and retaining soil on agricultural lands. By preserving fertile topsoil, terraces maintain soil productivity and prevent land degradation, which is essential for climate change adaptation.
- **Enhanced biodiversity and ecosystem resilience:** Terraces provide habitat for a diverse range of plant and animal species, promoting biodiversity conservation and ecological balance. This supports ecosystem resilience, as a diverse ecosystem is better equipped to adapt to climate change impacts.
- **Sustainable livelihoods and rural development:** The combined adoption of drip irrigation and terraces contributes to sustainable rural development by improving agricultural productivity and preserving natural resources. This enhances livelihoods, particularly for smallholder farmers, and reduces their vulnerability to climate change-induced risks.

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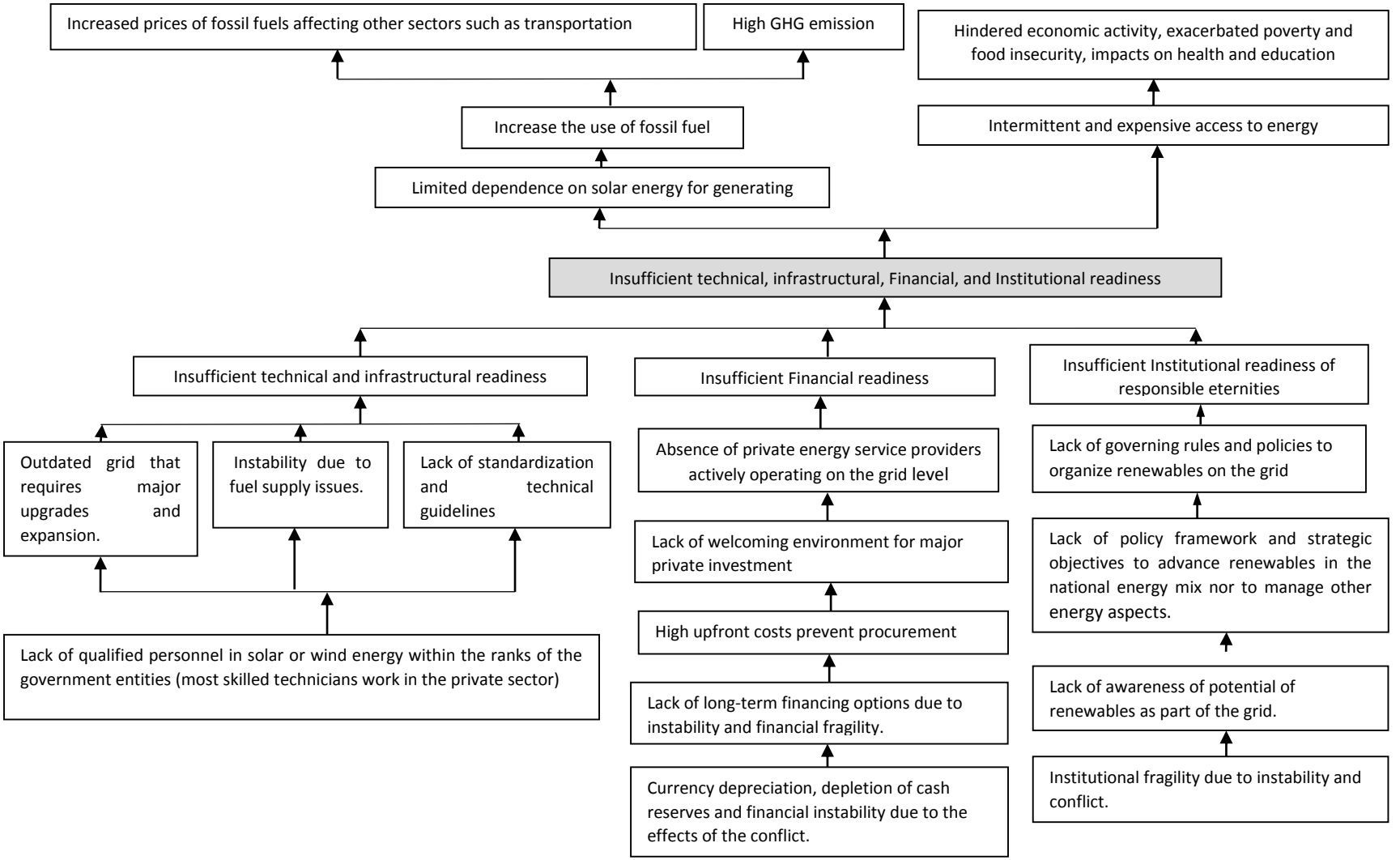
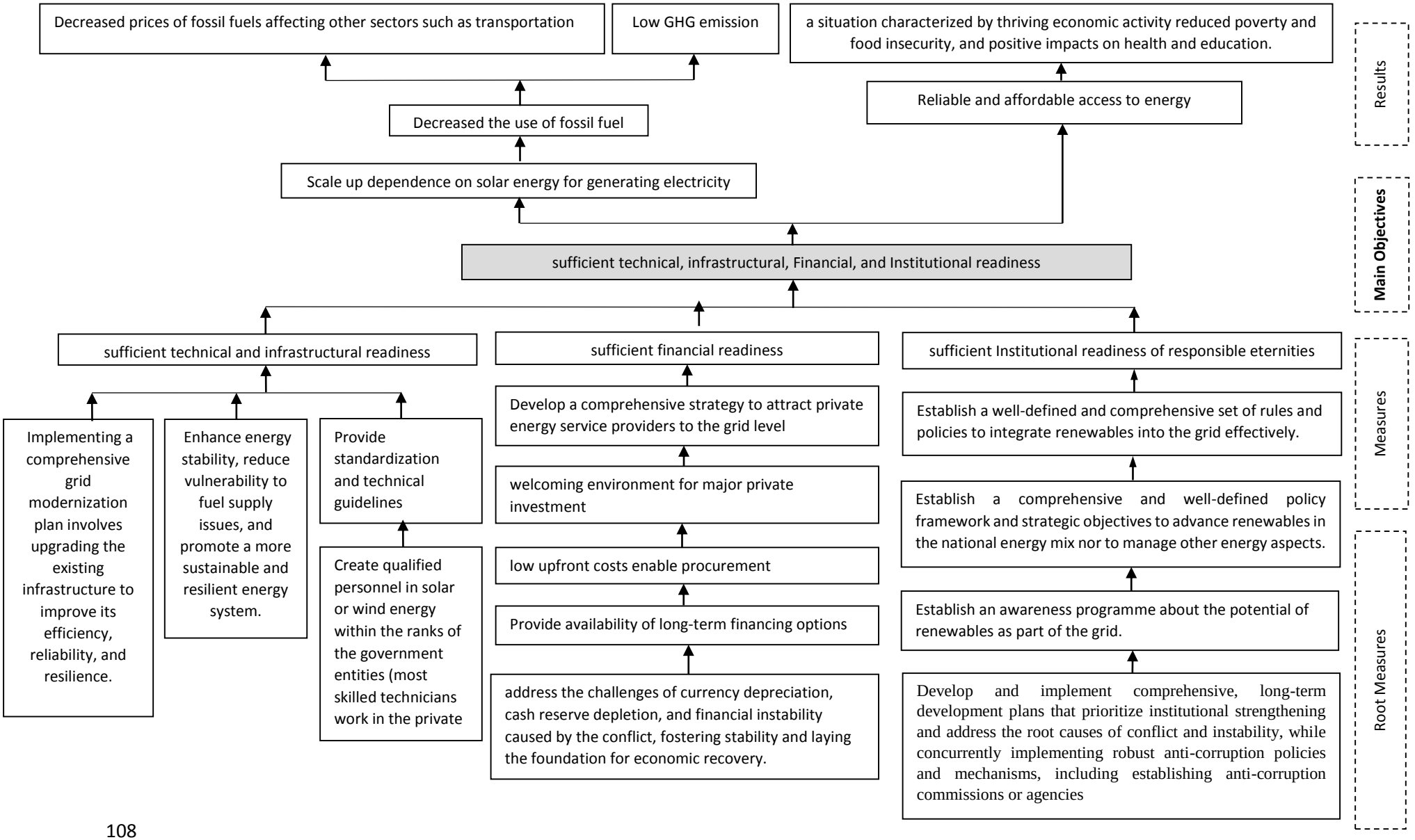
Annexes I: Market Mapping and Problem-Solution Trees

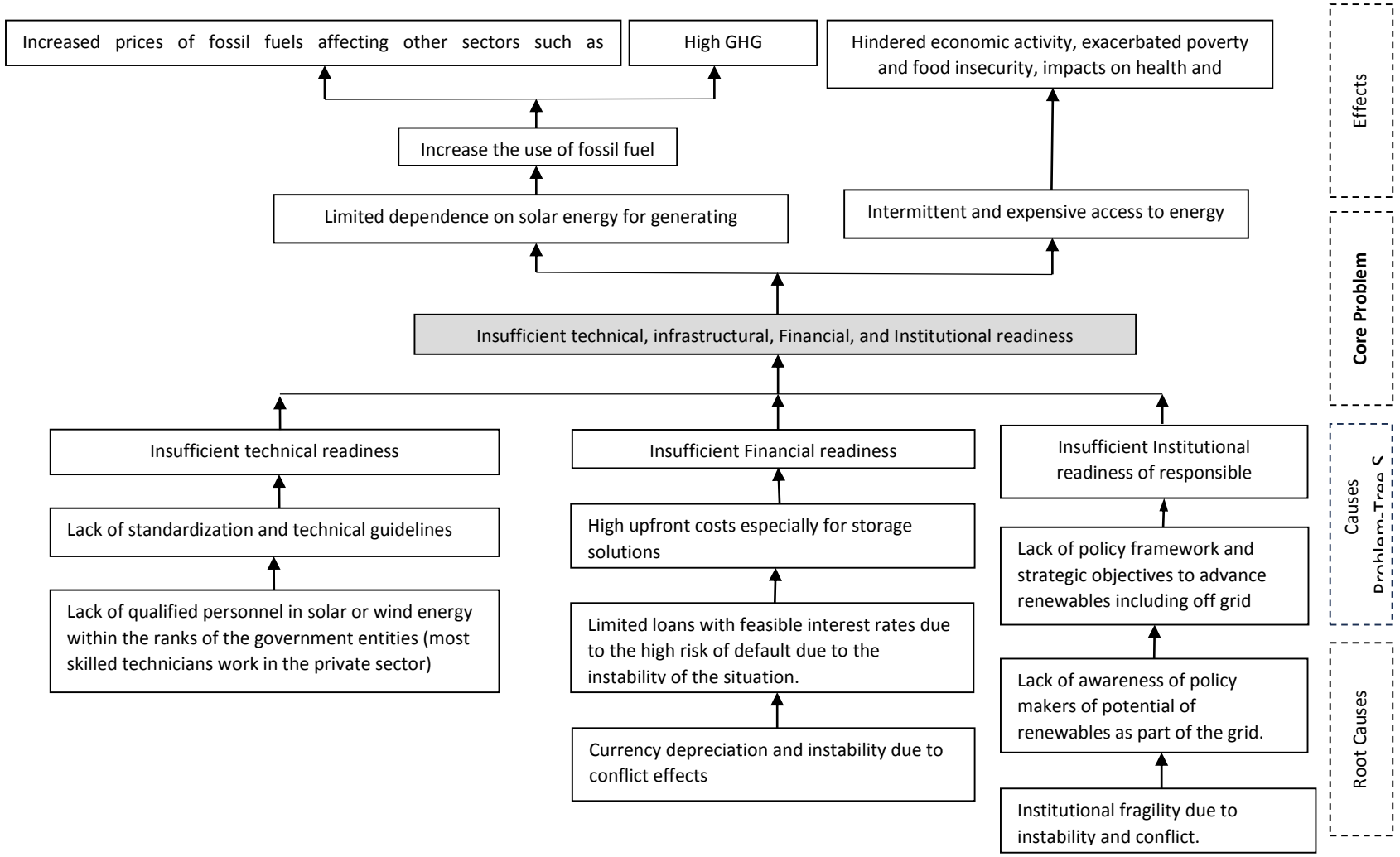
Annex1-1: Problem-Tree for the Energy Sector: Photovoltaics Solar (PV) On-Off Grid System



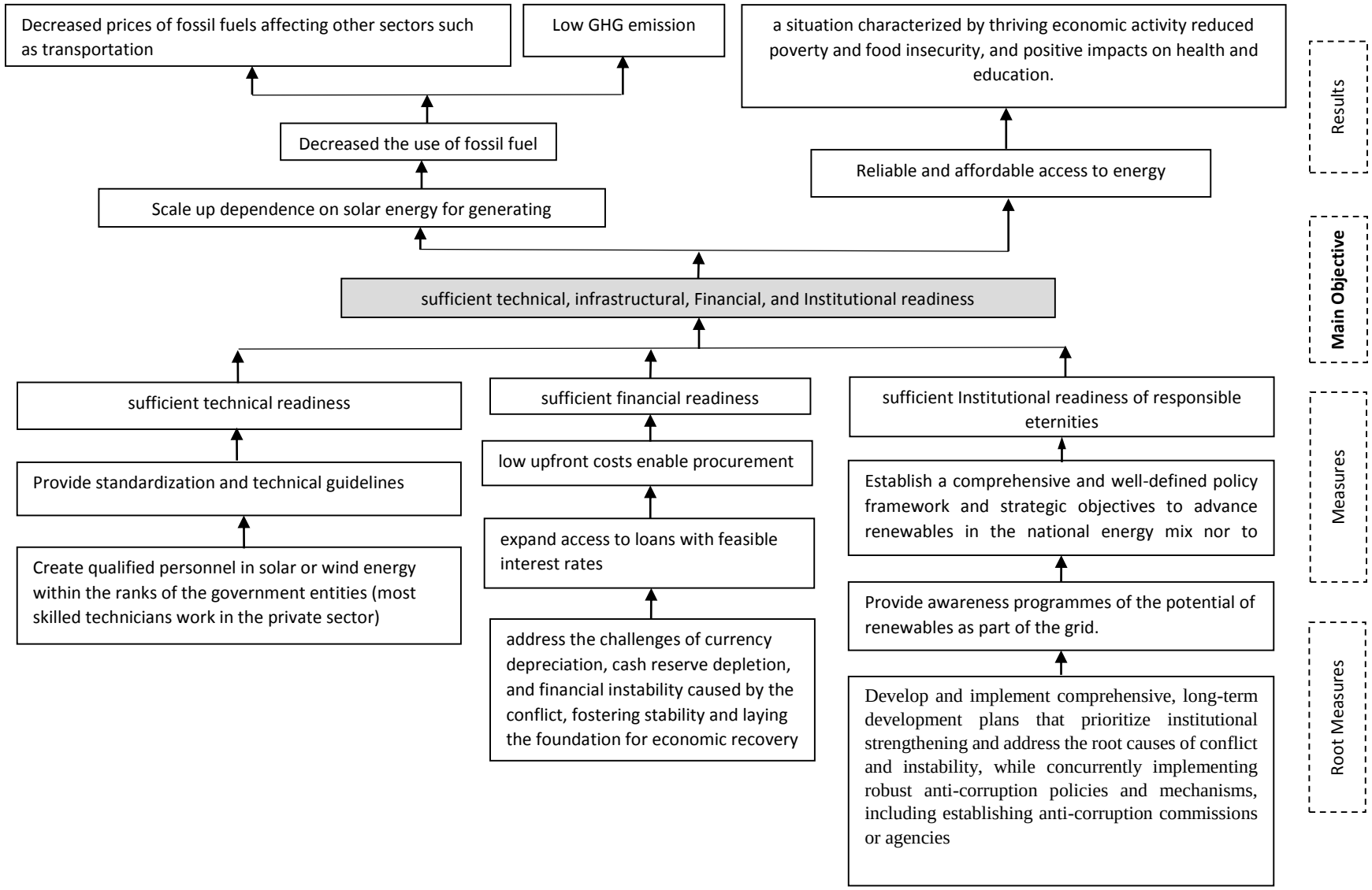
Annex1-2: Solution-Tree for the Energy Sector: Photovoltaics Solar (PV) On-Off Grid System



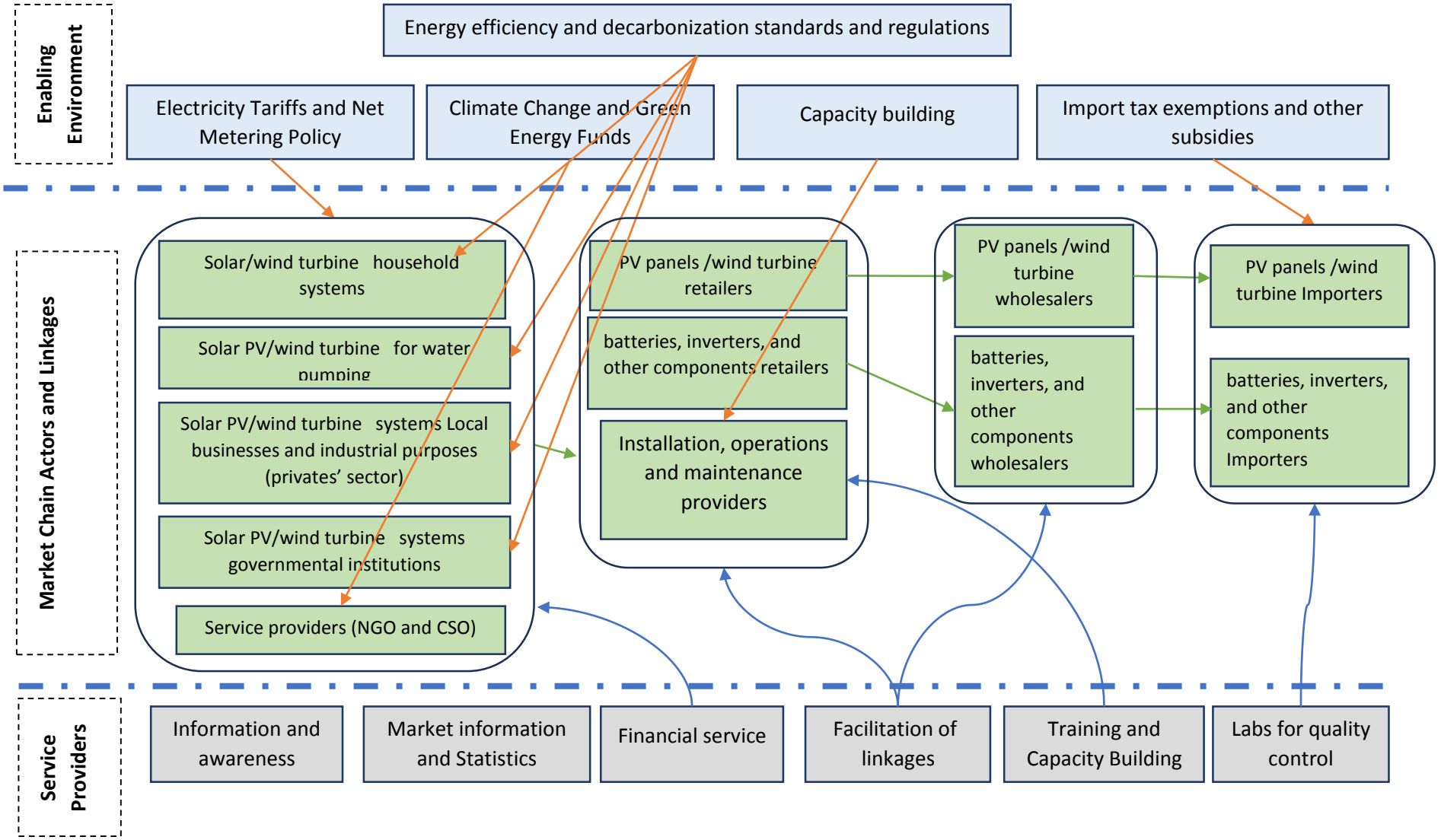
Annex1-3: Problem Tree for the Energy Sector: Wind Turbine On-Off Grid System



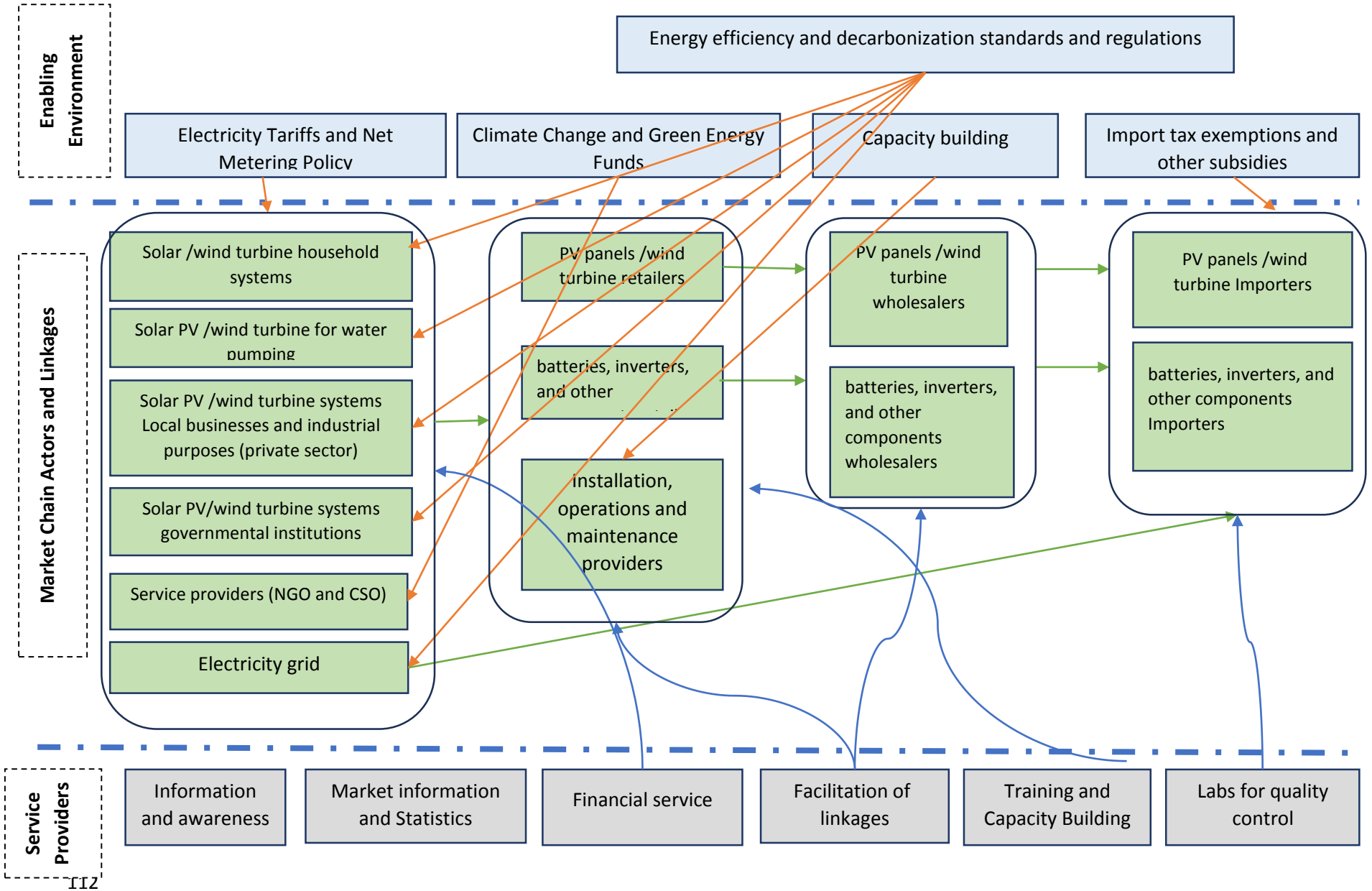
Annex1-4: Solution Tree for the Energy Sector: Wind Turbine On-Off Grid System



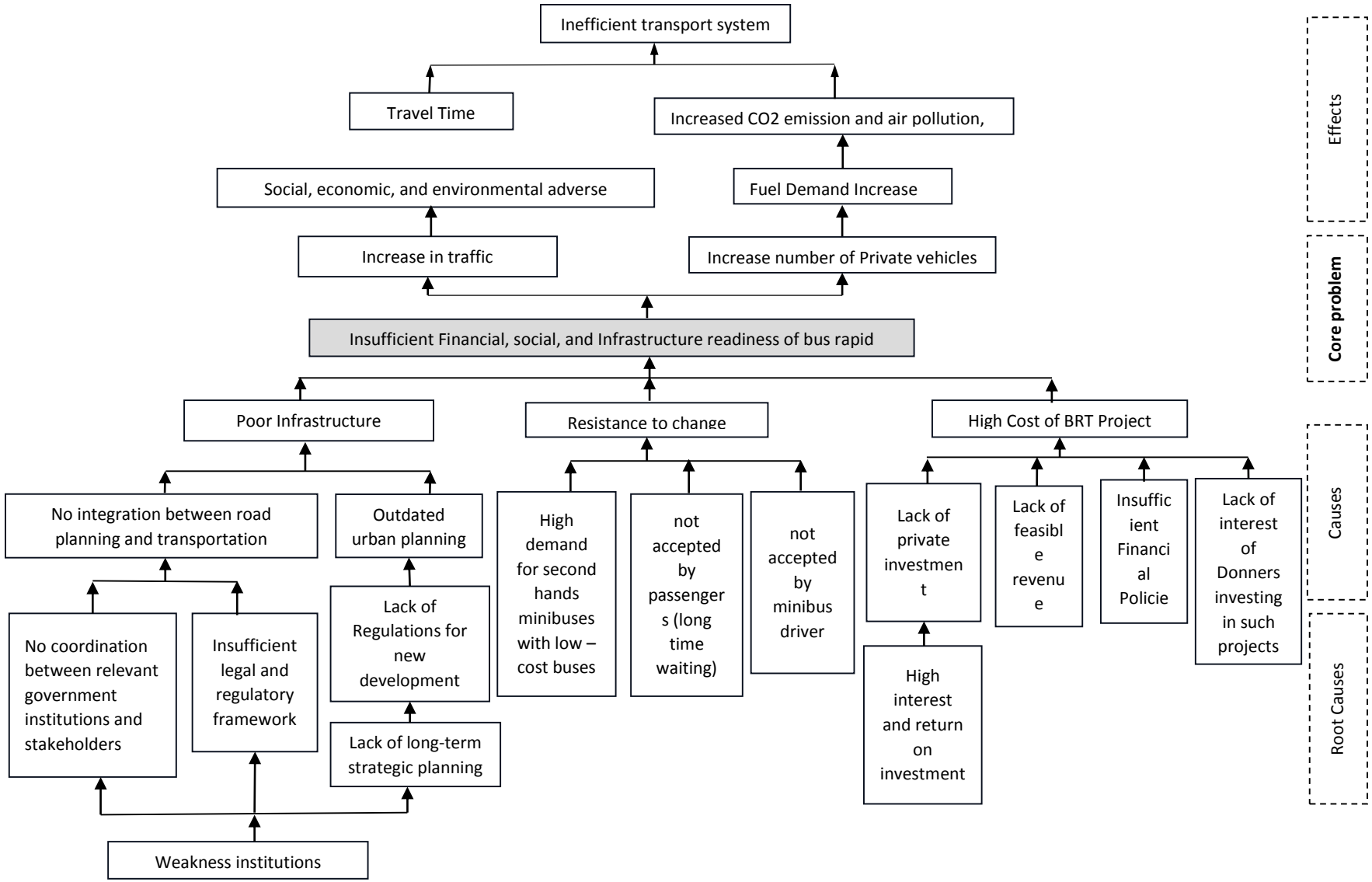
Annex1-5: Market Map for the Energy Sector: Photovoltaics Solar (PV) /wind turbine Off Grid System



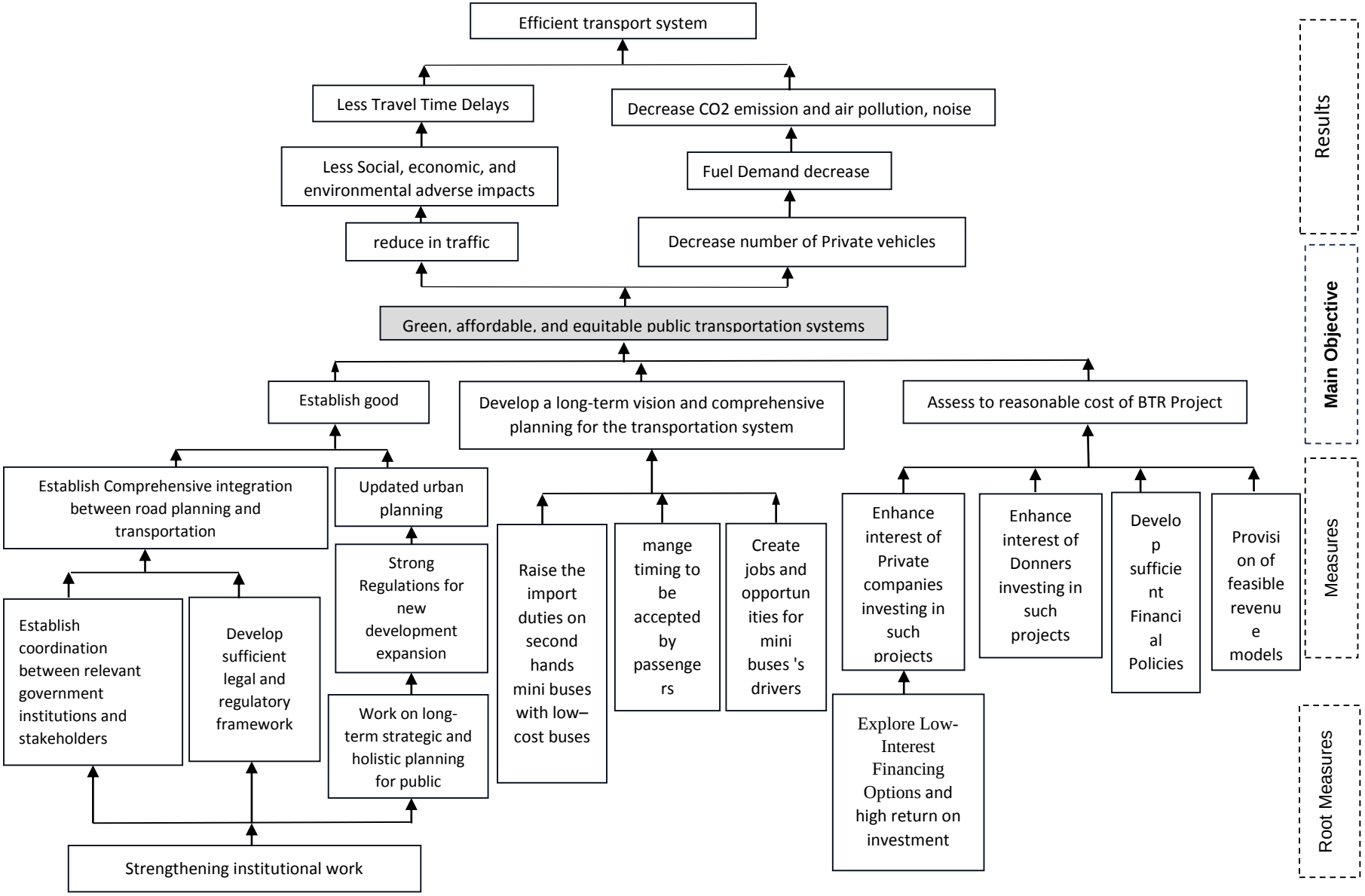
Annex1-6: Market Map for the Energy Sector: Photovoltaics Solar (PV) /wind turbine on Grid System



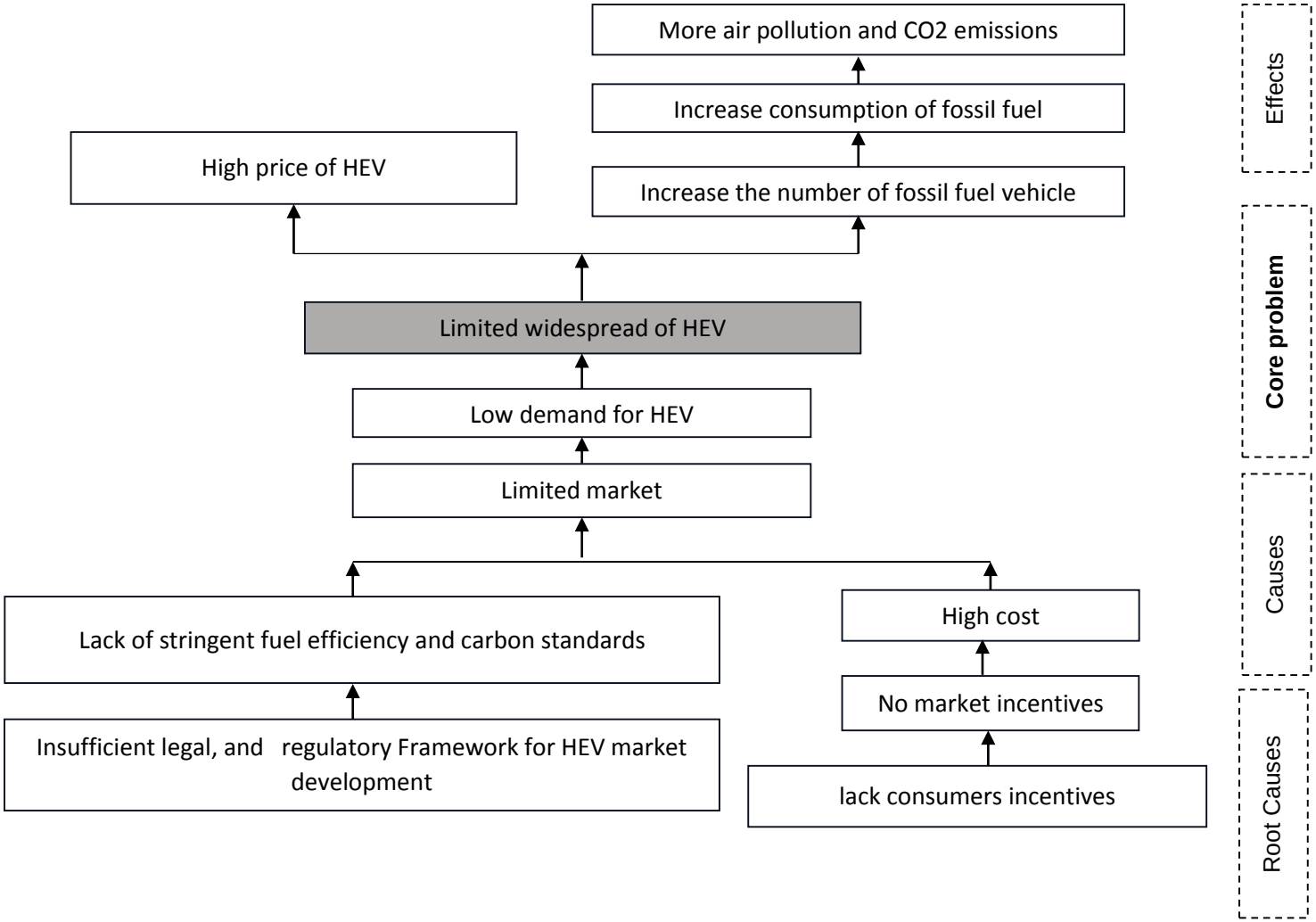
Annex 1-7: Problem Tree for the Transport Sector: Bus Transit Rapid (BTR)



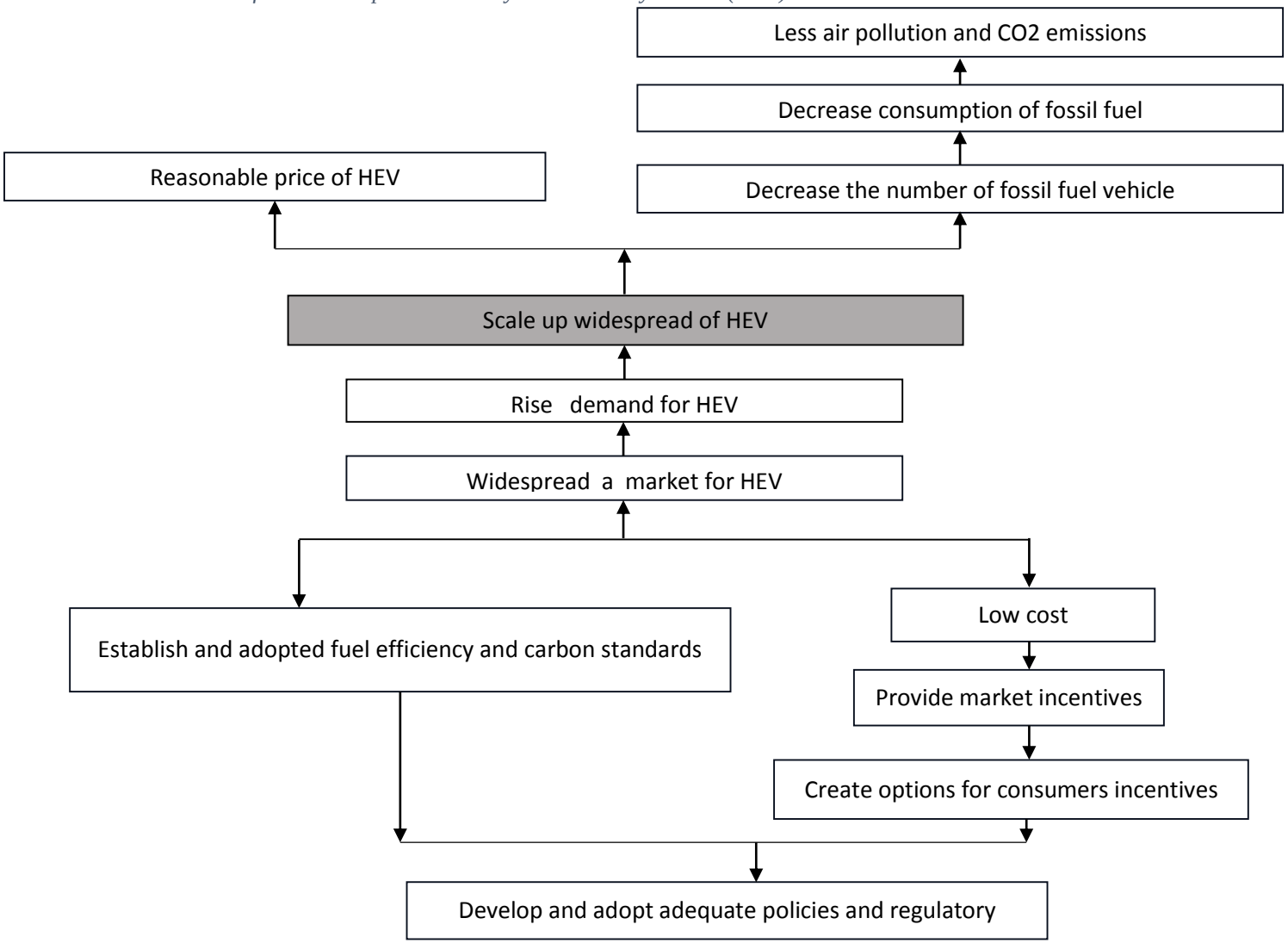
Annex 1-8: Solution Tree for the Transport Sector: Bus Transit Rapid (BTR)



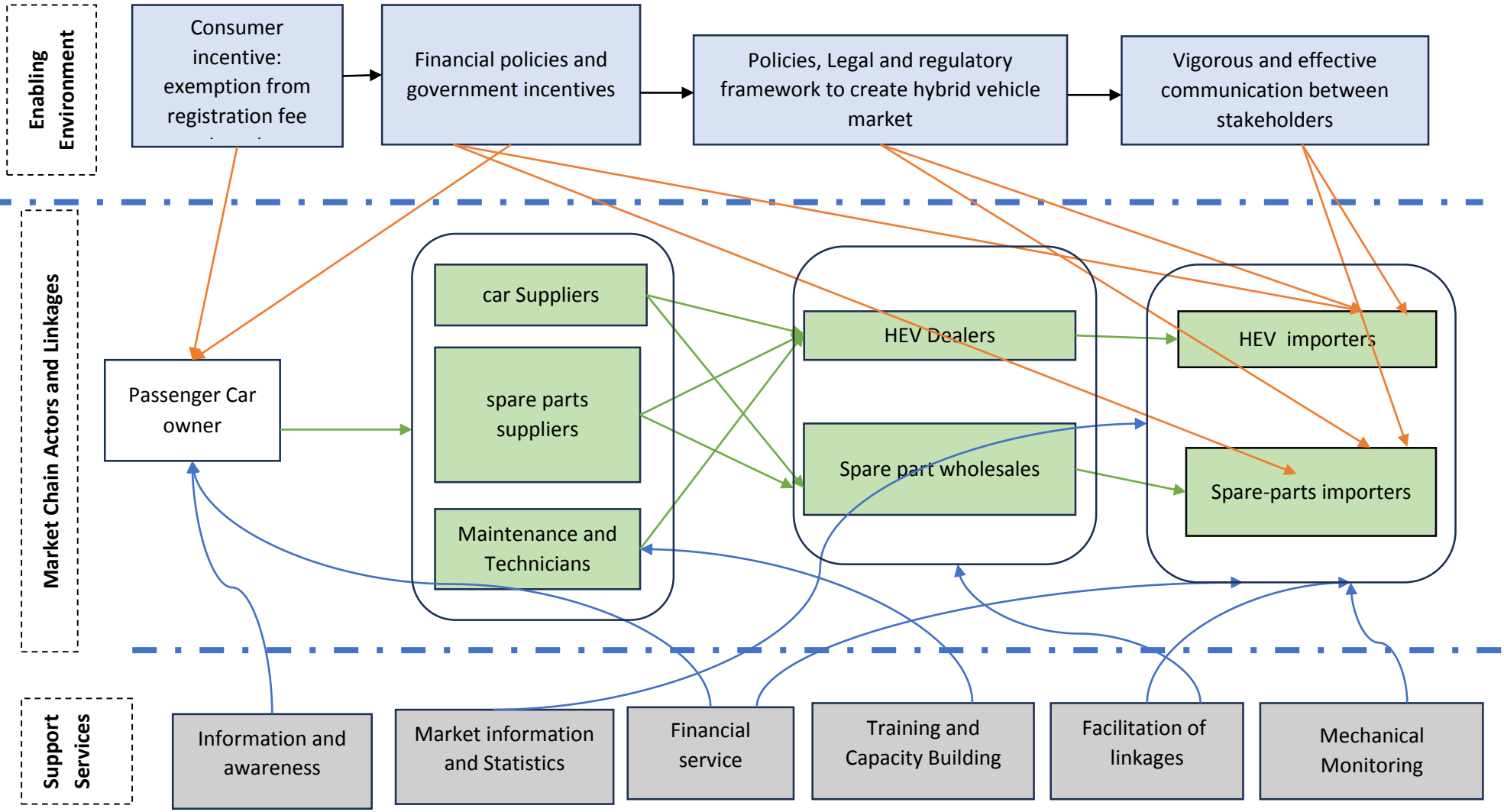
Annex 1-9: Problem Tree for the Transport Sector: Hybrid electricity vehicle (HEV)



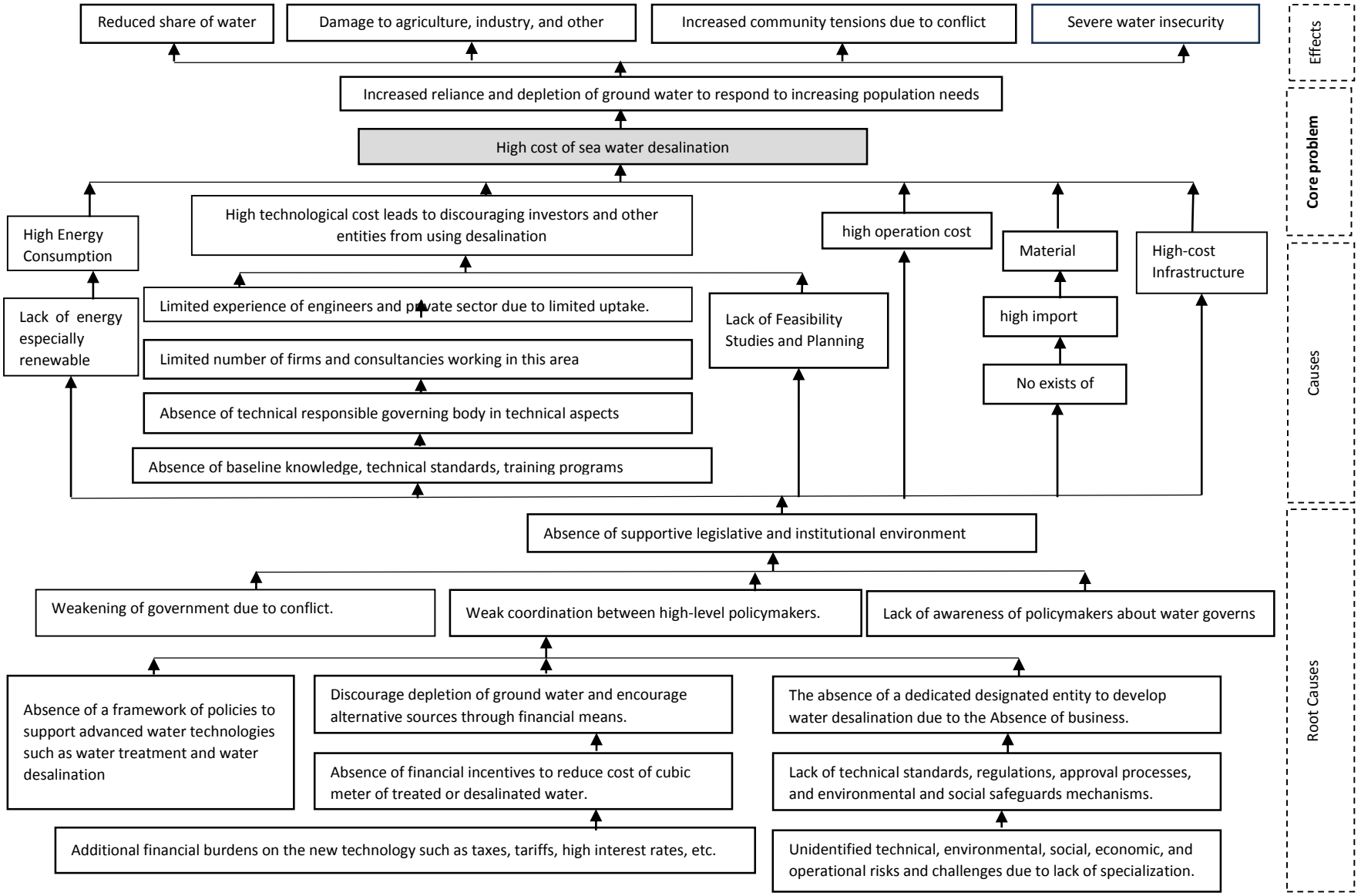
Annex 1-10: Solution Tree for the Transport Sector: Hybrid electricity vehicle (HEV)



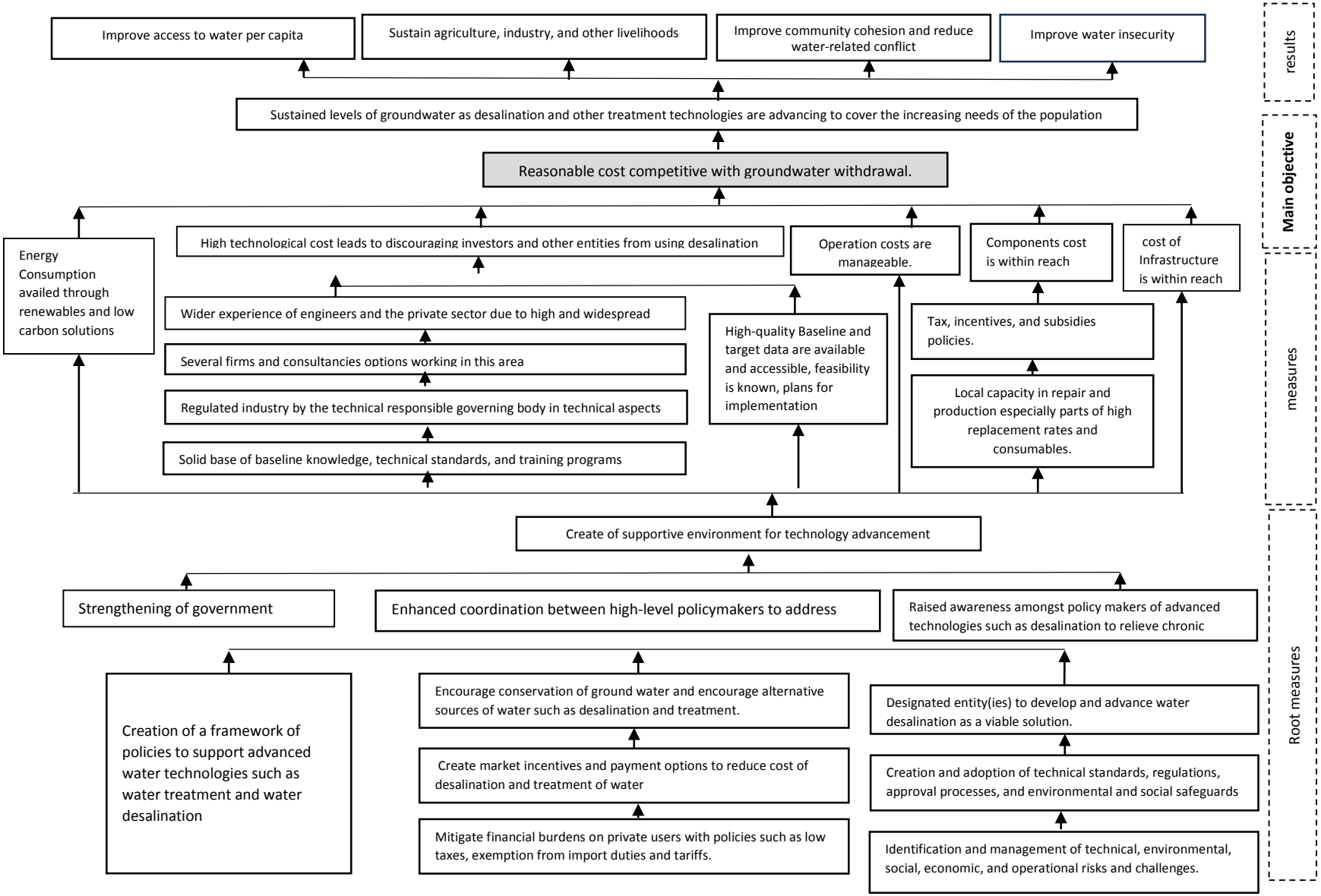
Annex1-11: Market Map for the Transport Sector: Hybrid electricity vehicle (HEV)



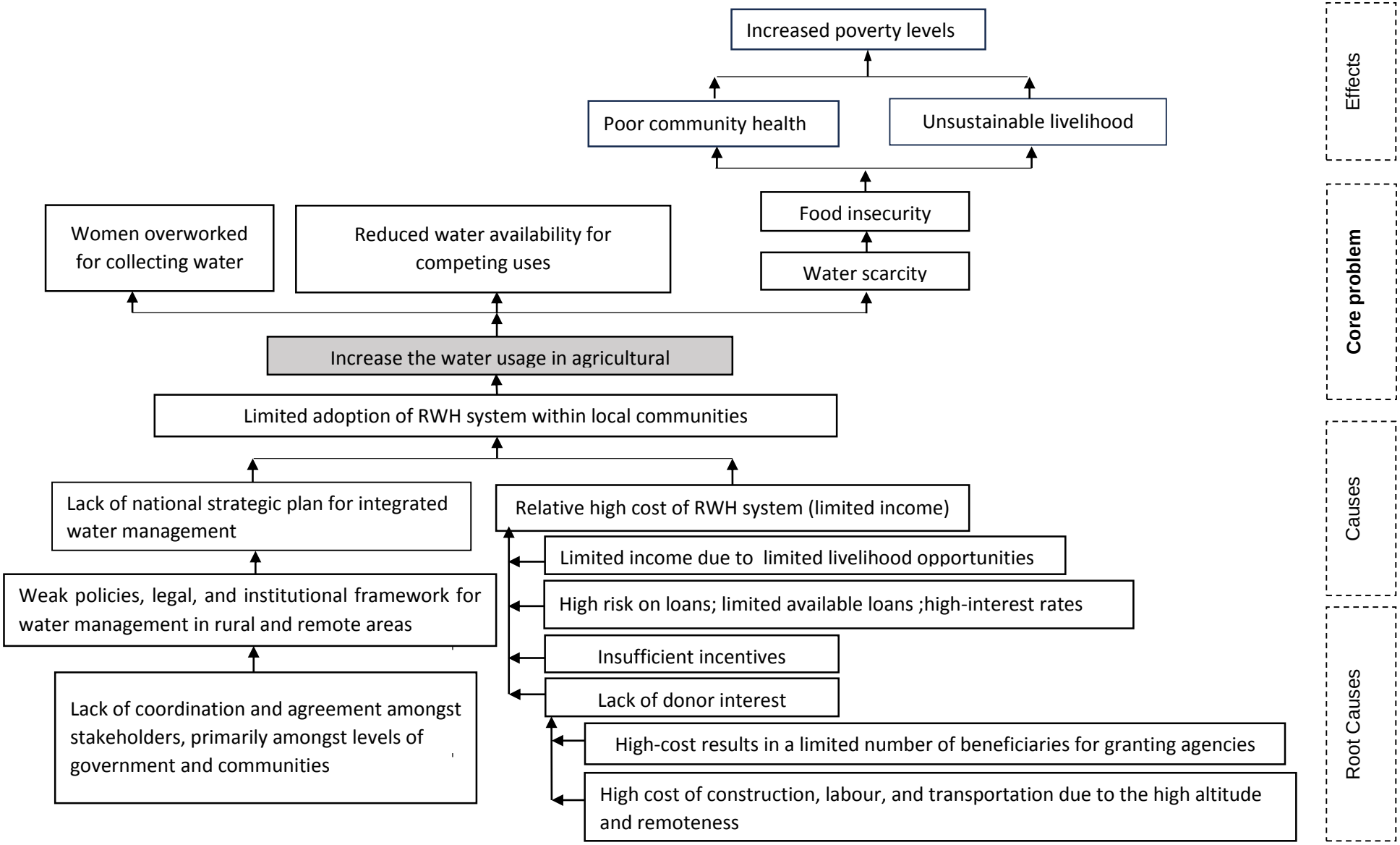
Annex 1-12: Problem -Tree for the water Sector: sea water desalination



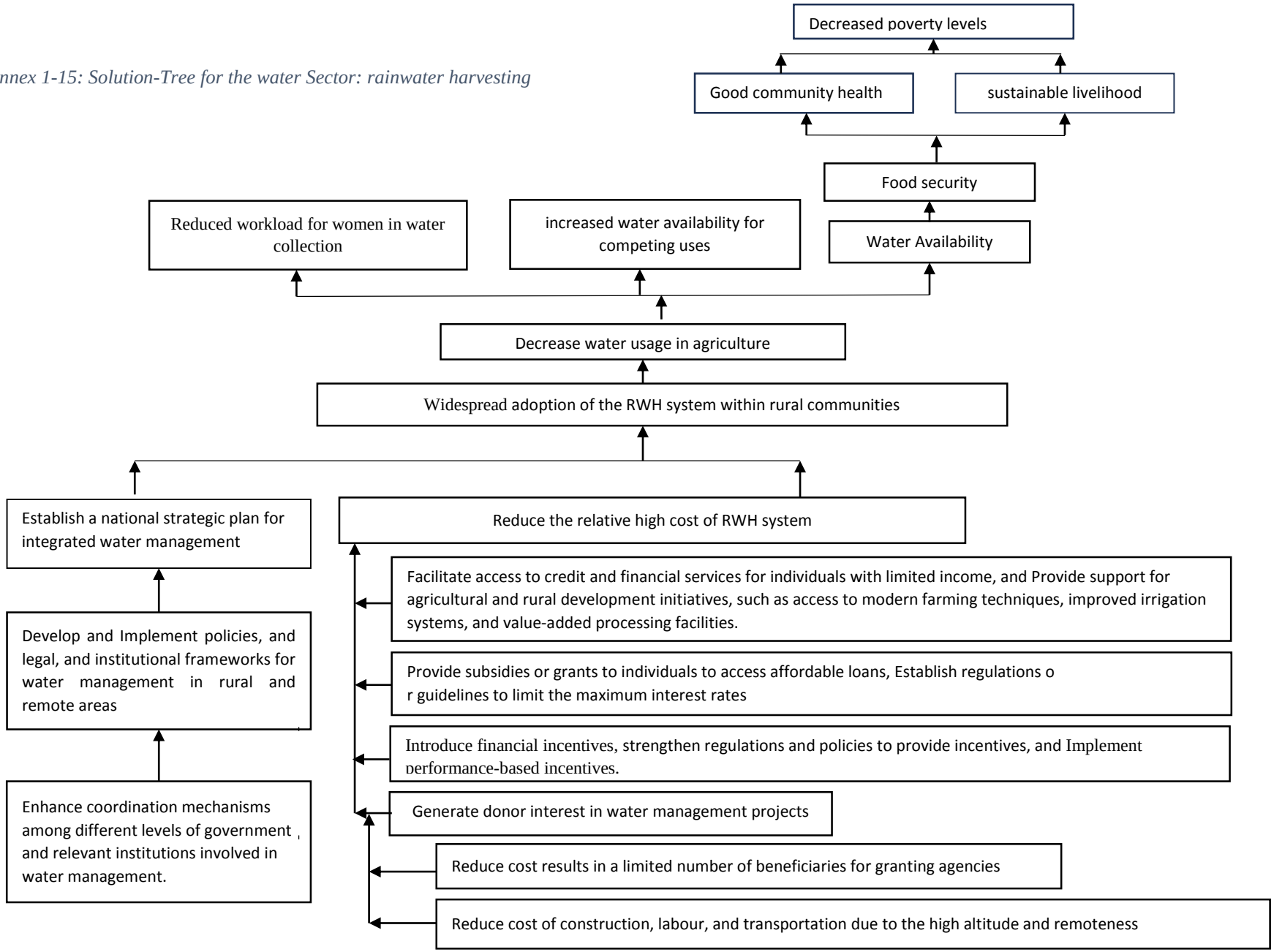
Annex 1-13: Solution -Tree for the water Sector: sea water desalination



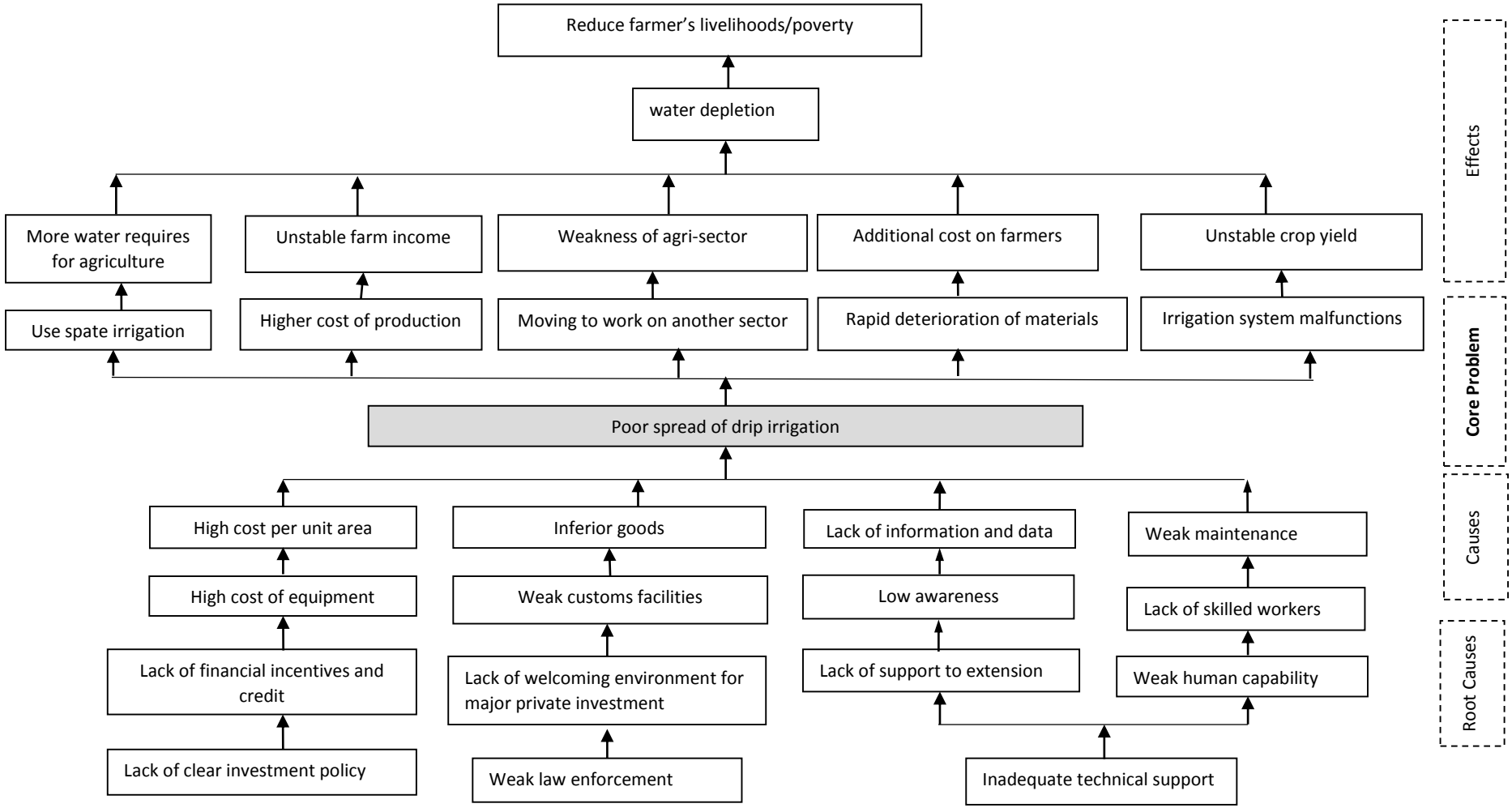
Annex1-14: Problem -Tree for the water Sector: rainwater harvesting



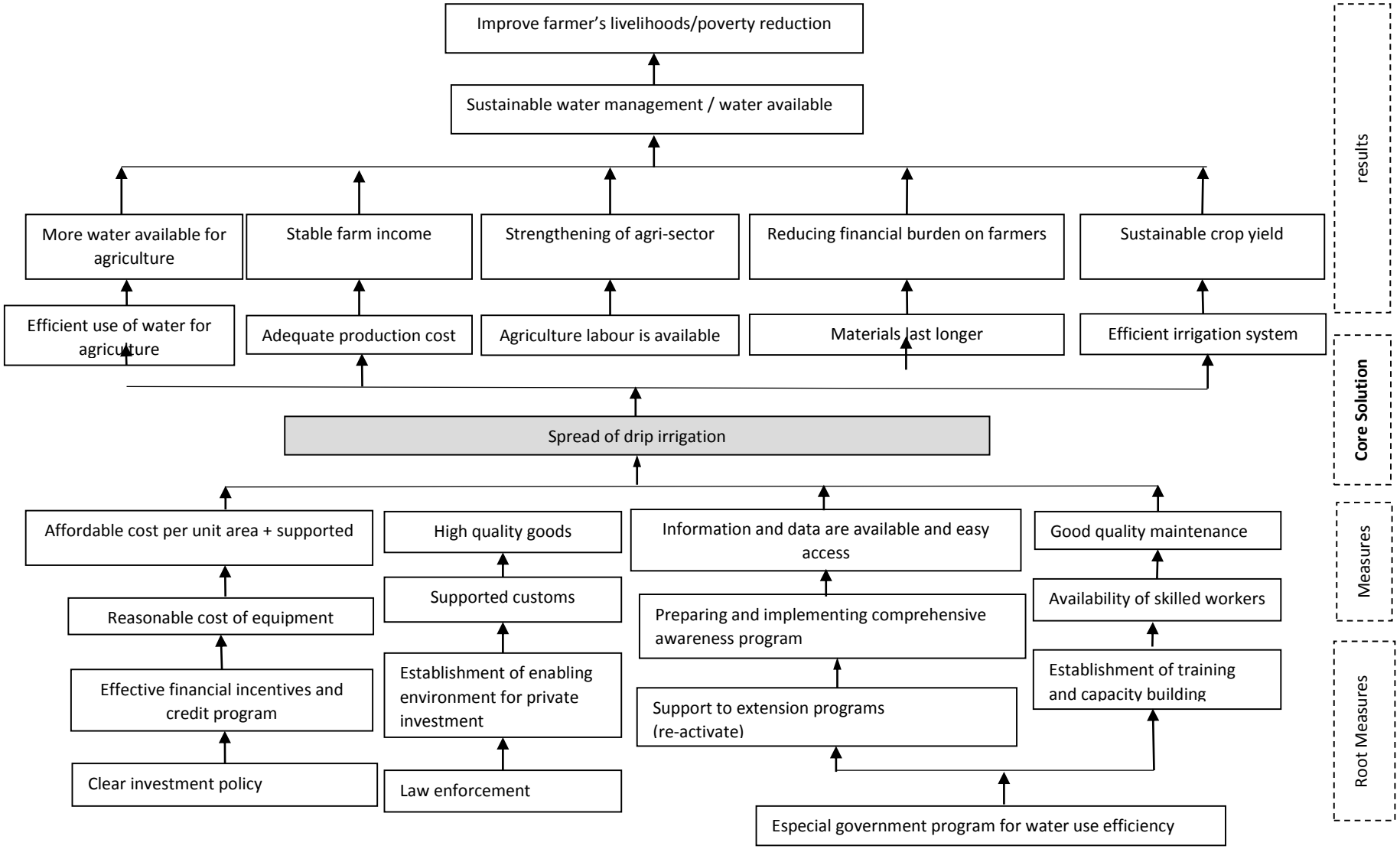
Annex 1-15: Solution-Tree for the water Sector: rainwater harvesting



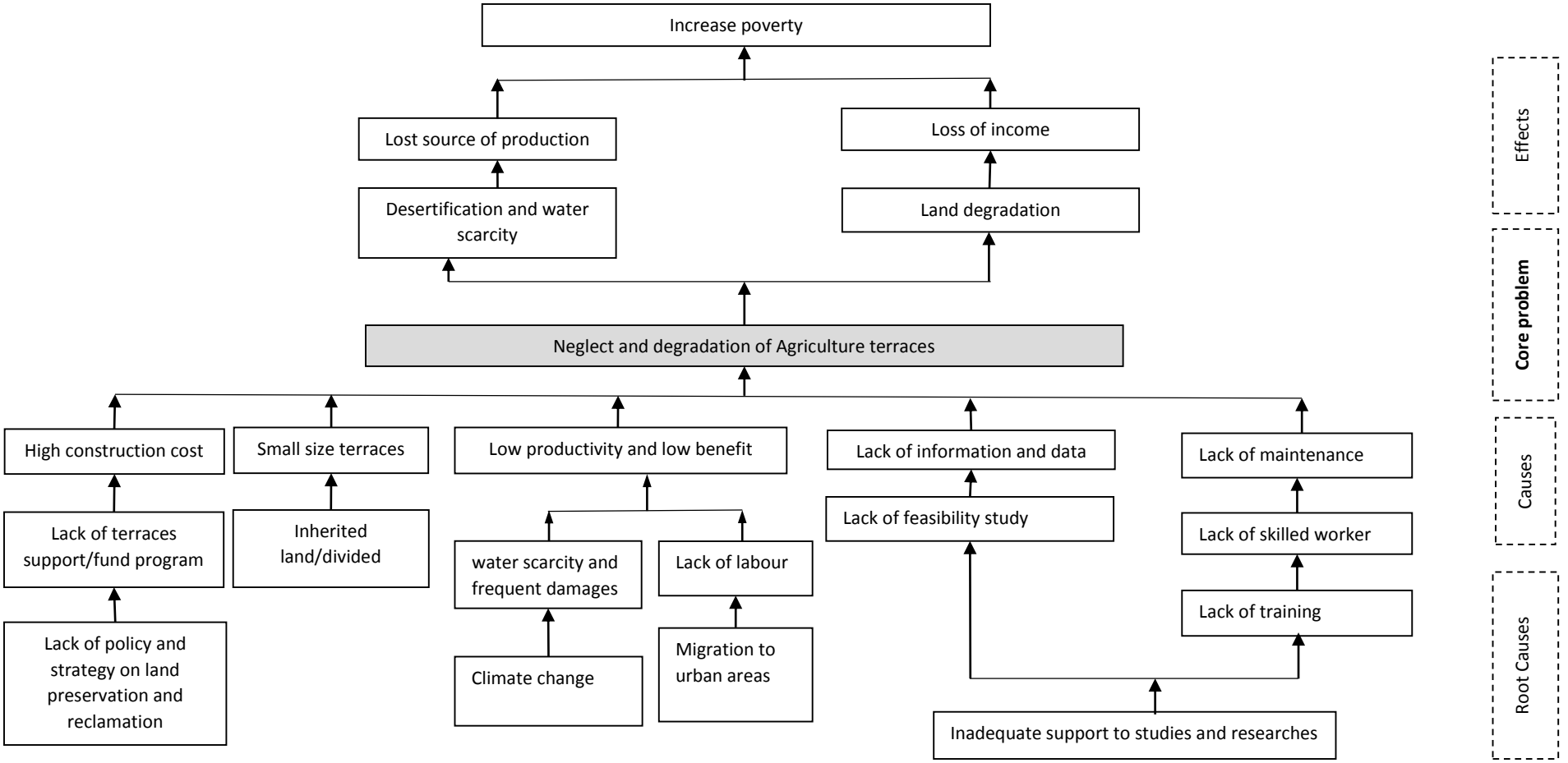
Annex 1-16: Problem-Tree for the Agricultural Sector: Drip irrigation



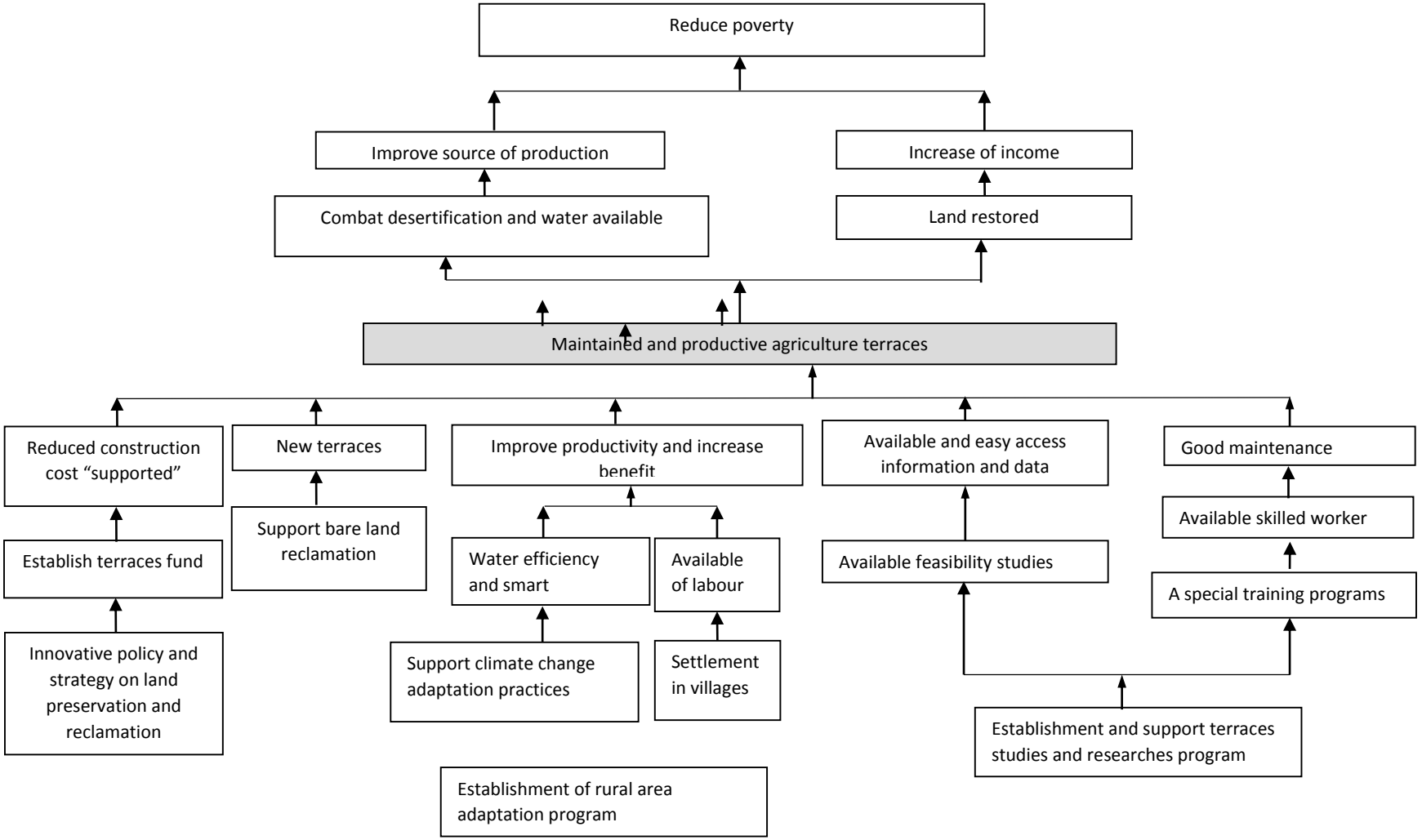
Annex 1-17: Solution-Tree for the Agricultural Sector: Drip irrigation



Annex 1-18: Problem Tree for the Agricultural Sector: Terraces



Annex 1-19: Solution Tree for the Agricultural Sector: Terraces.



Annex II: Roster of stakeholders participated in the BA&EF report and Validation workshop held in 7th -8th November 2023

Consultation Approach	NO.	Name	Entity	Sector	Date
Individual meetings and questionnaires	1.	Nagib Mohammed Noaman	Ministry of Water and Environment	water	May
	2.	Ahmed Nasser Al-Zamki	Ministry of Agriculture and Irrigation	Agriculture	October
	3.	Abdul Hakim Fadel	Ministry of Electricity and Energy،	Energy	August
	4.	Abdul Malik Naji	Ministry of Agriculture and Irrigation	Agriculture	October
	5.	Abdul Hakim Alaiah	Ministry of Water and Environment	Environment	May
	6.	Abdulbaree A-kadasi	Ministry of Water and Environment	Water	August
	7.	Edaros Alsaow	Social Fund for Development	Water	October
	8.	Arafat Amir	Lahj-university	Water	August
	9.	Khalid Belaidi	National Water Resources Authority, NWRA	water	June
	10.	Abdulaziz Mahiub	National Water Resources Authority, NWRA-Aden	Water	October
	11.	Khalid Shoja	National Water Resources Authority, NWRA-Lahj	water	July
	12.	Mohammed Bahamed	National Water Resources Authority, NWRA-Hadramout	Water	June
	13.	Najiba Muammar Abdel Wahab	National Water Resources Authority, NWRA	water	October
	14.	Nawras Barakat	Aden Transport Office	Transport	July
	15.	Saeed Bamshams	Toyota Commercial Centre for Cars and Engines	Transport	August
	16.	Abdul Wahid Alsakaf	Commercial Director Hyundai Company	Transport	October
	17.	Fares Shafal	General Authority for the Regulation of Land Transport Affairs	Transport	July
	18.	Abdul Bari Al-Harbi	General Transport Corporation	Transport	August
	19.	Fadl Al-Abadi	Ministry of Transport,	Transport	October
	20.	Abdullah Ahmed Baradi	Director of the Centre for Renewable Energy Studies and Research, Hadramaut University	Energy	July
	21.	Akram Abdul Rahman Qasim Muharram	Electrical engineer and specialist in the free zone port/Aden	Energy	July
	22.	Adham Sorour	HSA group	Energy	June
	23.	Ismail Noureddine Ismail Saeed	HSA group	Energy	October
	24.	Muhammad Abdullah Salem Al-Hamdi	Pearl gulf of aden laboratories	Energy	August

	25.	Mohamed Abdulla salem Alhamdi	Total Gas Company	Energy	October
	26.	Bassam Muhammad Abdullah Ali	Technical education and vocational training	Energy	June
	27.	Fawad Bishr	Agricultural Irrigation Department	Agriculture	July
	28.	Ahmed Al-Shaabi	Land Reclamation Department	Agriculture	June
	29.	Ayman Al-Samawi	Al Badda Factory-Sanaa	Agriculture	July
	30.	Walid Saleh	FAO-Yemen	Agriculture	August
	31.	Mazen Aman	HSA group	Transport	June
	32.	Rafiq Al-Kubati	CAC Bank	Agriculture	October
	33.	Khaled Al-Aji	Amal Bank	Agriculture & Water	September
Workshops	1.	Faisal Saleh Al-Thalabi	Environment Protection Authority, HQ (Chairman)	Environment	**7&8 November**
	2.	Nayef Ali Saleh Mosaad	Ministry of Water and Environment	Water	
	3.	Yasser Abdo Al-Ghubair	Ministry of Water and Environment	Water	
	4.	Jamil Abdo Saeed Moqbel	Ministry of Water and Environment	Water	
	5.	Najiba Muammar Abdel Wahab	National Water Resources Authority, NWRA	Water	
	6.	Mohammed Saeed Al-Aqrabi	National Water Resources Authority, NWRA	Water	
	7.	Mansour Jaafar Ali	National Water Resources Authority, NWRA	Water	
	8.	Ahmed Nazim Mohammed Ali	General Water and Sanitation Corporation, HQ	Water	
	9.	Abdullah Mohammed Baobid	Nahda Makers Organization	Water	
	10.	Mustafa Mohammed Salem Qasim	Care Origination	Water	
	11.	Wajdi Hussein Saleh Abd Rabbo	Environment Protection Authority, HQ	Agriculture	
	12.	Fathi Abdullah Al-Saaw	Environment Protection Authority, Lahj	Agriculture	
	13.	Maryam Jaafar Al-Saqqaf	Environment Protection Authority, Lahj	Agriculture	
	14.	Mohammed Abdullah Saad	Environment Protection Authority, Aden	Water	
	15.	Mustafa Mohammed Salem Qasim	Care Origination	Water	
	16.	Walid Abdul Rashid Yaqoub	UN-Habitat	Energy	
	17.	Huda Mansour Ahmed Seel	Environment Protection Authority, Lahj	Agriculture	
	18.	Ali Abdullah Al-Masahri	Environment Protection Authority, Abyan	Agriculture	

19.	Farouk Talib Ali	Ministry of Agriculture and Irrigation	Agriculture
20.	Abd Rabbo Ali Mohammed Al-Saadi	Ministry of Agriculture and Irrigation	Agriculture
21.	Shukri Fadl Saleh	Ministry of Agriculture and Irrigation	Agriculture
22.	Wadie Abdel Habib Abdul Sattar	Ministry of Agriculture and Irrigation	Agriculture
23.	Mohammed Salem Al Khashaa	Agriculture Research and Extension Authority	Agriculture
24.	Abdullah Ahmed Mohammed Muflhi	Agriculture Research and Extension Authority	Agriculture
25.	Abdullah Fadl Abdul Majeed	Agriculture Office, Lahj	Agriculture
26.	Hussein Fadl Saleh	Agriculture Office, Abyan	Agriculture
27.	Ahmed Muharen	Centre for Environmental Studies	Agriculture
28.	Ahd Mohammed Qaid Saeed	CAC Bank	Agriculture
29.	Khaled Nour Al-Din Hussein	CAC Bank	Agriculture
30.	Mohammed Khaled Mohammed Salem	Care Origination	Water
31.	Omar Nasser Ba-joba	Selah Foundation for Development	Water
32.	Askar Ali Omar Askar	Ministry of Planning and International Cooperation	Transport
33.	Sarah Al-Turki	Environment Protection Authority, HQ	Agriculture
34.	Faryal Manea Aljabr	Faculty of Engineering, University of Aden	Energy
35.	Hanan Al- Bayhani	Faculty of Engineering, University of Aden	Energy
36.	Najm Al-Din Saif	UNDP	Energy
37.	Entsar Saleh	UNDP	Transport
38.	Nizar Ahmed Ahmed	Ministry of Planning and International Cooperation	Transport
39.	Hossam Ahmed Al-Mutili	The HSA Group	Energy
40.	Jamal Al Mazroui	The HSA Group	Energy
41.	Khaled Faisal Bin-Talib	Ministry of Electricity and Energy	Energy
42.	Rana Al-Abd Ali	Ministry of Electricity and Energy	Energy
43.	Fatima Saleh Badr Al-Khader	Ministry of Electricity and Energy	Energy
44.	Nisreen Nasser Saleh	Ministry of Electricity and Energy	Energy
45.	Abdul Qader Salem Al-Aidaroos	Al-Aidaroos Solar	Energy

46.	Afaf Abdullah Youssef Saleh	Ministry of Industry and Trade	Energy
47.	Mohammed Aidaroos Zein	UN-Habitat	Energy
48.	Fahmi Nasser Ali	Ministry of Transportation	Transport
49.	Ali Mohammed Nasser Abu Bakr	General Authority for Land Transport Regulation	Transport
50.	Abdullah Ahmed Abdullah Al-Yousifi	Natco Automotive	Transport
51.	Waheed Abdullah Ghanem	General Authority for Land Transport Regulation	Transport
52.	Aidaroos Hashem Al-Zahr	Ministry of Transportation	Transport
53.	Kafeel Abdul Hakim Saleh	Ministry of Transportation	Transport
54.	Jalal Mohammed Qasim Abdullah	Ministry of Transportation	Transport
55.	Aidaroos Hussein Al-Duwailah	Customs Authority	Energy
56.	Abdullah Karama Abdullah Al Nahari	Customs Authority	Energy
57.	Abdullah Salem Salumi	Ministry of Public Works and Highways	Transport
58.	Saleh Abu Bakr Saleh	Public Works and Highways Office	Transport
59.	Omar Ahmed Omar Youssef	Ministry of Industry and Trade	Energy
60.	Ashraf Mohammed Khanbari	Chamber of Commerce and Industry	Energy
61.	Abdo Ahmed Othman Saeed	Public Works and Highways Office	Transport

TNA Focal Points in the relevant entities

Name	Entity	Contact no
Mansour Jaafar Ali	National Water Resources Authority, NWRA	+967 775165091
Aidaroos Hashem Al-Zahr	Ministry of Transportation	+967 736316316
Khaled Faisal Bin-Talib	Ministry of Electricity and Energy	+967 771077272
Farouk Talib Ali	Ministry of Agriculture and Irrigation	+967 772857148

Annex III: Agenda of Validation Workshop

First Day: 07/11/2023

Identifying and analysing the market and non-market technologies in the field of adaptation

Time	Period	Activities	Duties
9:00-8:30	30 m	Registration	Secretary
9:15-9:00	15 m	Session1: Opening Statement of the Chairman of EPA	Chairman of EPA
9:35-9:15	20 m	Session 2: Summary of phase one, selected technologies in adaptation, the importance of the second phase, and its objectives	TNA team
9:45-9:35	10 m	Session 3: methodology used to analyse the barriers and measures	TNA team
10:00-9:45	15 m	Session 4: Briefing Presentation on barriers and measures in the agricultural sector	Agricultural consultants' team
10:00:10:15	15 m	Session 5: Brief presentation on barriers and measures in the water sector	Water consultants' team
-10:15 10:30	15 m	Session6: Discussion	consultants' team and TNA team
-10:30 10:45	15 m	Coffee Break	
-10:45 11:45	60 m	Session 7: Working Groups: Identification of barriers and measures for the four selected technologies in Agricultural and Water-	consultants' team and TNA team
-11:45 12:15	30 m	Session 8: Working Groups- Presentation of the barriers and measures identified in Session 7, in Agriculture and Water	consultants' team and TNA team
-12:15 12:35	20 m	Session 9: Working Groups- Demonstration of Flow Charts (Problem and Solution Trees- Market Map) for barriers and measures identified in session 7.	TNA team
-12:35 01:05	30 m	Session 10: Working Groups-Presentation of Flow Charts of Problem and Solution Trees, Market Map)	consultants' team
1:20-01:05	15 m	Session 11: Presentation of Day 1 (Barriers and measures for the four selected technologies in Agriculture and Water	TNA team
1:30-1:20	10 m	Closing	TNA team

Second Day 08/11/2023

Identifying and analysing the market and non-market technologies in the field of mitigation

Time	Period		Duties
9:00-8:30	30 m	Registration	**Secretary**
9:20-9:00	20 m	Session 1: Summary of phase one, selected technologies in mitigation, the importance of the second phase, and its objectives	TNA team
9:30-9:20	10 m	Session 2: methodology used to analyse the barriers and measures	TNA team
9:45-9:30	15 m	Session 3: Briefing Presentation on barriers in the Energy sector	Energy consultants' team
10:00-9:45	15 m	Session 4: Brief presentation on barriers in the Transportation sector	Transportation consultants' team
10:15-10:00	15 m	Session 5: Discussion	consultants' team and TNA team
10:30-10:15	15 m	Coffee Break	
11:30-10:30	60 m	Session 6: Working Groups: Identification of barriers and measures for the four selected technologies in Energy and Transportation	consultants' team and TNA team
12:00-11:30	30 m	Session 7: Working Groups- Presentation of the barriers and measures identified in Session 6, in Energy and Transportation	consultants' team and TNA team
12:20-12:00	20 m	Session 8: Working Groups- Demonstration of Flow Charts (Problem and Solution Trees- Market Map) for barriers and measures identified in session 7.	TNA team
12:50-12:20	30 m	Session 9: Working Groups-Presentation of Flow Charts of Problem and Solution Trees, Market Map)	consultants' team
1:05-12:50	15 m	Session 10: Presentation of Day 1 (Barriers and measures for the four selected technologies in Energy and Transportation)	TNA team
1:15-1:05	10 m	Closing	TNA team

Annex IV: Pictures of the Participants at the Validation Workshop.