ANTIGUA AND BARBUDA

TECHNOLOGY NEEDS ASSESSMENT
REPORT II

BARRIER ANALYSIS AND ENABLING FRAMEWORK REPORT
- WATER, BUILDING, TRANSPORT SECTOR -

December 2021

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EXECUTIVE SUMMARY

The Barrier Analysis and Enabling Framework (BAEF) is the second of three steps in the Technology Needs Assessment (TNA) process. The report focuses on the main barriers to the transfer and diffusion of six (6) technologies for the water sector, two (2) technologies for the building sector and four (4) technologies for the transportation sector. The proposed measures to address these barriers are then outlined and enabling frameworks to overcome them in a systematic process are presented. The Barrier Analysis maintained a strong focus on Antigua and Barbuda's Intended Nationally Determined Contributions (INDCs) and national targets to 2030 delineated for the State.

For this report, a barrier is defined as *"a reason why a target is adversely affected, including any failed or missing countermeasures that could or should have prevented the undesired effect(s)"* (Nygaard & Hansen 2015). The barriers examined were economic and non-economic – including institutional capacity, human resources, socio-cultural propensities, environmental concerns, and information and awareness. Thus, the Barrier Analysis was a rapid assessment tool used to identify causes hindering the achievement of the desired effect.

The structure of this report includes:

- A broad overview of the preliminary targets for technology transfer and diffusion - for each adaptation technology;
- The identification and prioritization of the barriers using a participatory process which included a desktop literature review, one-to-one stakeholder consultations, a Technology Working Group (TWG) session and field visit and consultation with the Barbuda Council. Following prioritization, *L*ogical *F*ramework *A*nalysis was used to decompose the highest-ranked barriers to find their root causes;
- The assessment of possible measures to address the barriers to transfer and diffusion and;
- The identification of enabling measures to enhance the uptake of each technology – presented in a framework.

The Consultants prepared initial lists of economic/financial and non-economic barriers for each technology based on background reviews of similar technologies, national climate change and development targets and knowledge of the local context. The lists were first presented to the TNA Steering Committee for approval prior to sharing them with stakeholders in consultative sessions.

Stakeholder working groups (SWGs) from the previous step were reorganized into technology working groups (TWGs) based on each stakeholder's expertise and interest. The TWGs reviewed the initial lists and prioritised barriers using a qualitative measure of 'relative importance' - '*high, medium or low'.* Barriers that were ranked 'high' in their level of importance were considered critical – having the potential to prevent successful technology transfer – and these were selected to be decomposed.

For each selected barrier, logical framework analysis was used to identify root causes and their effects; following which, enabling measures were identified to overcome them and the corresponding benefits for the Antiguan and Barbudan society were identified. The prioritized barriers shared common attributes related to *high* capital, implementation, and operation costs, *need for increased* education and awareness, *limited* market availability and incentives for pairing complementary technologies and the *need for* institutional and organizational reform within public sector agencies.

Enabling measures were used to create frameworks to support widescale diffusion of each technology. Each sectoral framework outlined *measures*; *benefits, expected timeframe, projected costs* and *agencies or entities* critical to the transfer and diffusion of each technology. The TWGs identified potential partners – from the public and private sectors – who would be involved in technology transfer, along with an estimate of the projected costs based on existing research and reports done prior to the TNA project. These frameworks are the precursors for the development of Technology Action Plans in the next TNA step.

Successful technology transfer in Antigua and Barbuda will require a combination of activities, processes and agencies focused on building capacity and resilience to climate change. Social, economic, and environmental indicators must be carefully selected, clearly stated, measurable and consistent with national development objectives and climate change goals. The Technology Action Plan (TAP) will be used to outline how successful technology transfer and diffusion can be achieved.

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LIST OF ACRONYMS

AC:	Alternating Current
APUA:	Antigua Public Utilities Authority
BAEF:	Barrier Analysis and Enabling Framework
CBA:	Cost-Benefit Analysis
DC:	Direct Current
DCA:	Development Control Authority
DoE:	Department of the Environment
DTU:	Technical University of Denmark
ESIA:	Environmental and Social Impact Assessment
GEF:	Global Environment Facility
GoAB:	Government of Antigua and Barbuda
INDC:	Intended Nationally Determined Contributions
IPCC:	Inter-governmental Panel of Climate Change
IWRM:	Integrated Water Resources Management
NASAP:	National Adaptation Strategy and Action Plan
NODS:	National Office of Disaster Services
PSA:	Public Service Announcement
PV:	Photovoltaic
RWH:	Rainwater Harvesting
SIDS:	Small Island Developing States
SIRF:	Sustainable Island Resource Framework
TAC:	Technical Advisory Committee
TAP:	Technology Action Plan
TNA:	Technology Needs Assessment
TWG:	Technology Working Group
UDP:	UNEP-DTU Partnership
UNEP:	United Nations Environment Programme
UNFCCC:	United Nations Framework Convention on Climate Change

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1. PROCESS FOR THE IDENTIFICATION OF BARRIERS AND MEASURES

1.1. OBJECTIVE AND METHODOLOGY FOR THE BARRIER ANALYSIS

1.1.1. Objectives

In this second step of the TNA – the Barrier Analysis and Enabling Framework (BAEF) – the process seeks to identify barriers that could potentially hinder acquisition and diffusion of the prioritized sector technologies, and thereafter develop enabling frameworks to overcome the most critical barriers. Through a fully participatory process, as outlined in the TNA guidebook series, "Overcoming Barriers to the Transfer and Diffusion of Climate Technologies" (Nygaard & Hansen 2015), the overall objectives were to:

i.) Identify the economic and non-economic barriers for each technology;
ii.) Prioritize to select a maximum of three critical (killer) barriers;
iii.) Identify root causes and possible measures to overcome these critical barriers; and
iv.) Outline an enabling framework to overcome the barriers.

1.1.2. Methodology

The consultative process included sectoral literature reviews, one-to-one consultations with key water sector stakeholders, technology working group (TWG) sessions and culminated with a field visit and consultation with the Barbuda Council.

<u>Literature Review</u>

A review of the Environmental Protection and Management Act (EPMA) 2019, Sustainable Island Resource Management and Zoning Plan for Antigua and Barbuda 2011 and Integrated Water Resources Management (IWRM) Roadmap along with other relevant national regulations and policies, followed by the examination of case studies from context-similar Small Island Developing States (SIDS) was undertaken as the initial step. An analysis of Grenada's TNA process was particularly useful since this OECS country bears several similarities to Antigua and Barbuda. The resulting information was used to create an exhaustive list of possible barriers for each prioritized water sector technology.

Similar reviews were conducted for the building and transport sectors, with particular focus on analysing the information presented in Antigua and Barbuda's Intended Nationally Determined Contributions (INDCs), the Second and Third National Communications on Climate Change, the *draft* OECS Building Code and Antigua and Barbuda's Energy Transition Initiative Paper. These documents were useful in outlining the current context in-country and allowed the Consultant to create the initial list of barriers for each building and transport sector technology.

Barriers were grouped into two main categories: i.) economic and financial and ii.) non-financial; with the latter grouping including institutional capacity, human resources, socio-cultural propensities, environmental concerns and information and awareness. The lists were presented to the TNA Project Steering Committee – the Technical Advisory Committee (TAC) of the Department of Environment (DoE) – for review, following which they were refined and disseminated via email communication to members of the technology working groups (TWGs) in preparation for one-to-one consultations and TWG sessions.

One-to-one Consultations

The water sector Consultant initiated the barrier prioritization with a series of one-to-one consultations with members of the TWG. This strategy was chosen to focus individual interests and expertise, and garner maximum participation and input. The water sector technologies were subdivided into two groups: i.) market and ii.) non-market goods *(detailed in Section 1.2.)*, and stakeholders were chosen to prioritize barriers for selected technologies. Table 1 and Table 2 list the stakeholder agencies, interests, number of stakeholders engaged, gender and method of consultation, for each group of technologies. Initial attempts to meet with representatives from the Antigua and Barbuda Meteorological Services, Ministry of Agriculture – Extension Division and National Office for Disaster Services (NODS) were unsuccessful; however, their contributions during the TAC meeting and subsequent follow-up added value to the process. A full list of stakeholders can be found in Annex A.

Table 1: Categorization of Key Water Sector Stakeholders for Market Goods

MARKET GOODS					
AGENCY/DEPT.	INTERESTS				NOTES
	Economic	Political	Environmental	Community Development	
APUA	X		X		No.: 2 Gender: 2 M Method: P
Barbuda Council	X	X	X	X	No: 8 Gender: 4 M|4 F Method: P
Community Dev. Div. | Min. of Social Transformation				X	No.: 3 Gender: 1 M|2 F Method: P|T
Chamber of Commerce	X				No.: 1 Gender: M Method: P
Bureau of Standards	X				No.: 1 Gender: F Method: P
Barnes Hill Com. Dev. Org	X	X	X	X	No.: 1 Gender: M Method: P

MARKET GOODS					
AGENCY/DEPT.	INTERESTS				NOTES
	Economic	Political	Environmental	Community Development	
Freetown Com. Gp.	X		X	X	No.: 1 Gender: F Method: T
Solar Expert / Retailer	X	X			No.: 1 Gender: 1 M Method: T|P
Hardware Retailer	X				No.: 4 Gender: 3 M|1 F Method: T|P
DoE	X	X	X	X	No.: 5 Gender: 2 M|3 F Method: P

No.: Number of Stakeholders | Gender: M-Male; F-Female | Method: E-Email; P: In-person; T-Telephone

Table 2: Categorization of Key Water Sector Stakeholders for Non-Market Goods

NON-MARKET GOODS					
AGENCY/DEPT.	INTERESTS				NOTES
	Economic	Political	Environmental	Community Development	
APUA	X		X		No: 3 Gender: 3 M Method: T | P
Barbuda Council	X	X	X	X	No: 8 Gender: 4 M|4 F Method: P
Agriculture Extension Div.*	X	X			No.: 1 Gender: M Method: E
National Parks			X		No.: 2 Gender: 2 M|1 M
Community Dev. Div. | Min. of Social Transformation		X		X	No.: 1 Gender: 1 F Method: P
Solar Expert / Retailer	X				No.: 1 Gender: M Method: P
DoE	X	X	X	X	No.: 5 Gender: 2 M|3 F Method: P

No.: Number of Stakeholders | Gender: M-Male; F-Female | Method: E-Email; P: In-person; T-Telephone

During one- to two-hour consultations, working group members were allowed to refine, reject, remove, add, and finally prioritize barriers using their knowledge of and expertise in the water sector and local market. Stakeholders were engaged in robust discussions to highlight cause and effect of the most significant barriers and clear measures were identified to address each cause.

At the end of the round of consultations, a tally of combined prioritization sheets was used to eliminate low scoring barriers, while the highest scorers were designated *critical / killer* barriers. Problem / Solution tree analysis was utilized to collate stakeholder input and present a pictorial representation of the results of the consultations.

Technology Working Group Sessions

On Tuesday, February 11th, 2020, water sector stakeholders assembled to review findings and reach a group consensus of barriers, causes and enabling measures. This provided an opportunity for shared learnings and experiences across TWGs and facilitated a process where the collective presented the totality of results.

Problem trees provided the basis for discussions and aggregate contributions from the group were used to amend/refine the proposed root causes and enabling measures. Input from the TWG session resulted in the reconstruction of Problem and Solution Trees for *Wa*ter *S*aving *D*evices and follow up discussions were used to finalize the causes and measures.

The TWG sessions for the building and transport sectors were held in separate three-hour sessions on Tuesday February 18th, 2020. The Consultant moderated spirited discussions with the stakeholder groups as the teams reviewed the barriers and ranked them based on the perceived level of influence they would likely have on the adoption of each technology. In addition to ranking, stakeholders gave vital input on the primary causes of the barriers and steps that must be taken to overcome them. The Consultant later used this collective information to develop Problem and Solution Trees for each technology.

Consultation and Field Visit to Barbuda

The combined TNA team visited the island of Barbuda for a day of consultations on Wednesday, February 19th, 2020. The Barbuda Council convened a special meeting to accommodate the visiting TNA team, and the morning session was spent in discussions around the global TNA Project, Antigua and Barbuda's priority sectors and prioritized technologies, and specific applications for Barbuda. The afternoon session was spent in the field, where the team visited natural water catchments, the island's reverse osmosis (RO) desalination facility and areas in Cordington adversely impacted by and not yet rehabilitated following the passage of *superstorm* Hurricane Irma in September 2017.

The composition of the Council allowed for optimum gender representation and input from both male and female perspectives *(see* Table 3*)*. Female council members highlighted concerns surrounding household storage and complementary pumping, while the males were more focused on the potential for increased business opportunities in the agriculture sector, and there was a cross-cutting concern relating to Utility performance, infrastructure, and in-home appliances. The Council members also highlighted concerns about coding, removal of vegetation that can potentially be used as natural wind breaks and the positioning of homes / buildings to lessen the impact of storms. It was the general consensus that homeowners, investors, architects and builders must all be fully aware of the pros and cons of maintaining mature vegetation.

Table 3: Gender Representation on the Barbuda Council

	MALE	FEMALE
Barbuda Council Chair		X
Barbuda Member of Parliament	X	
Barbuda Council Members	4	4

Figure 1 shares highlights from the TWG session and field visit to Barbuda.

TWG Discussions at the DoE (Antigua)

Discussion with Barbuda Council members (Barbuda)

Figure 1: Highlights from Technology Working Group Sessions
Photo Credit: DoE | TNA Project

1.1.3. Prioritization of Barriers

The prioritization of barriers was completed in three stages – executed in the pre-described methodology *(see Section 1.1.2.)*. In the initial stage, the Consultant facilitated the TAC and technology working group stakeholders in brainstorming barriers for each technology. Each listed barrier was thoroughly analysed and screened; and the ones deemed essential – based on stakeholders' knowledge of the local context, professional experience and lessons learned from local applications – were retained for further examination.

1.1.3.1. Water Sector Technologies

The process then progressed to **selection and categorization**, where the Consultant's expert judgement and the TWG's insight were employed to classify barriers based on perceived importance. Stakeholders assigned *High (H)* to critical or killer barriers which would adversely affect or prevent diffusion; *Medium (M)* to important barriers which should be monitored and *Low* (L) to those barriers deemed insignificant in the overall implementation process.

A numerical hierarchy was used to assign a **ranking** to the critical or killer barriers, and a maximum of the three (3) highest ranked barriers were selected to be decomposed using *logical framework analysis*. The template utilized in categorization and ranking is illustrated in Table 4.

Table 4: Categorization and Prioritization Process for Barriers

CATEGORIZATION OF BARRIERS – TECHNOLOGY X					
CATEGORY	BARRIER	LEVEL OF IMPORTANCE			
		HIGH	MED	LOW	RANK
ECONOMIC & FINANCIAL	Barrier A	X			2
	Barrier B		X		
	Barrier C		X		
NON-FINANCIAL	Barrier A			X	
	Barrier B		X		
	Barrier C	X			1
	Barrier D	X			3

Using the TNA guidelines, and Painuly (2001) steps for decomposition, each critical barrier was decomposed to identify the relationship between causes and their effects. Logical framework analysis provided a useful method of systematically bringing together the key elements of the barrier/problem and analysing how elements might be interlinked. The process of decomposition occurred at four levels:

i. broad categories of barriers – e.g., financial;
ii. barriers within a category – e.g., availability of financial resources to community NGOs;
iii. elements of barriers – e.g., number of national lending agencies/programs; and
iv. dimensions of barrier elements – e.g., range of concessionary loans available to community projects

Following decomposition, a range of measures was highlighted to address the root causes – thus overcoming the barriers. Cross-cutting barriers were identified to show linkages across water sector technologies. While all inter-linked barriers were discussed, the focus was maintained on critical / killer barriers; allowing for a wide range of measures to be captured in the enabling framework.

1.1.3.2. Transport and Building Sector technologies

The barriers presented were categorized by 'economic and financial barriers' and 'non-economic and financial barriers.

Each listed barrier was thoroughly analysed and screened; and the ones deemed high -priority – based on stakeholders' knowledge of the local context, professional experience and lessons learned from local applications – were retained for further examination.
Stakeholders were instructed to rank the barriers to the technologies presented, from the greatest barrier to the least effective barrier, from a set list of barriers. Stakeholders were also encouraged to present their own assumed barriers.

With this information gathered, a problem tree was developed to represent the main barriers ranked by the stakeholders throughout the session. The problem tree was used to determine the cause of each technology's difficulty in allocation or adoption in Antigua and Barbuda.

Finally, a range of measures was highlighted to address the root causes – thus overcoming the barriers. Cross-cutting barriers were identified to show linkages across the sectoral technologies. While all inter-linked barriers were discussed, the focus was maintained on critical barriers; allowing for a wide range of measures to be captured in the enabling framework.

<u>Presentation of barriers and Measures</u>

After the list of barriers and measures were ranked and prioritised based on the stakeholder engagements, they were presented to the TNA Project Steering Committee – the Technical Advisory Committee (TAC) of the Department of Environment (DoE). This was to ensure that they agreed with the barriers and measures prioritised while providing any additional feedback along with any further suggested edits based on their concerns.

<u>Other Local Expertise Consultations</u>

Additional research and data collection were done through engagement with other stakeholders that were not involved in the initial engagement where prioritization of the barriers and revision was done. The persons consulted are considered experts in the building and transport sector given their years of experience and contributions to the sector development in Antigua and Barbuda.

Their years of experience in the sector was vital given the fact they would have been involved in technology development and implementation in the past. Therefore, they were able to provide advice on the barrier and measures those past technologies endured for implementation. Further to this, they were also able to give their opinion on the technologies, relative to the enhancement of the sector, and provide feedback on some barriers and measures that should be considered.

1.2. CATEGORIZATION OF WATER SECTOR TECHNOLOGIES

The TNA process adopts the IPCC (2000) characterization that distinguishes between technologies that are diffused by the government (publicly transferred), private sector (the market) and communities (community NGOs or donor agencies). Table 5 shows that of the five (5) technologies prioritized for the water sector, three were considered *M*arket *G*oods, and further categorized as *C*onsumer *G*oods, and the other two *N*on-*M*arket *G*oods, in the sub-category of *P*ublicly *P*rovided *G*oods. It also defines the scale at which, *rainwater harvesting,* and *solar pumping systems* would be considered *C*apital *G*oods.

Table 5: Categorization of Prioritized Technologies for the Water Sector

TECHNOLOGY	MARKET GOODS		NON-MARKET GOODS	
	Consumer	Capital	Publicly Provided	Other Non-Market
Solar Pumping Systems Residential / Commercial	X			
Community-scale		X		
Rainwater Harvesting Residential / Commercial	X			
Community-scale		X		
Water-Saving Devices	X			
Climate-Proofing Assets			X	
Stormwater Reclamation and Reuse			X	
Atmospheric Water Generators Commercial	X			

In the consumer goods category, barriers could exist in any or all steps of the supply chain, and demand for these products would depend on consumer knowledge, awareness, and personal preferences. Market analyses are vital in determining the best steps to overcome barriers and promote diffusion. By contrast, publicly provided goods – particularly large scale, high-cost infrastructure projects implemented at the State level – are likely to encounter financial s*tarter* barriers along with institutional and socio-cultural barriers during implementation. Thus, integral steps would include both sourcing and securing of adequate capital financing and conducting in-depth socio-economic Cost-Benefit Analysis (CBA) and an Environmental Social Impact Assessment (ESIA).

1.3. CATEGORIZATION OF BUILDING SECTOR TECHNOLOGIES

All the technologies for the building sector were considered as market goods. Specifically, they were selected as consumer goods *(see Table 6)*. They can be implemented for residential, commercial, and public buildings and are expected to diffuse widely through society. Therefore, building sector professionals can use these technologies in a range of buildings.

Table 6: Categorisation of Technologies for the Building Sector

TECHNOLOGY	MARKET GOODS		NON-MARKET GOODS	
	Consumer	Capital	Publicly Provided	Other Non-Market
Passive House Design	X			
Best Roof Pitch Angle	X			
Impact Windows and Doors	X			
LED Lighting	X			
Energy Efficient Building Infrastructure Construction	X			

1.4. CATEGORIZATION OF TRANSPORT SECTOR TECHNOLOGIES

The transport sector technologies are a mix of market and non-market goods. Battery Electric Vehicles and solar charging stations are treated as consumer goods since they can be diffused to diverse users of current vehicles *(see Table 7)*. These technologies will be successful in reducing fossil fuel dependence only when the infrastructure is in place and cars are being charged with Renewable Energy (RE). Efficiency in the transport sector is a non-market good which would not be traded on any market. Improving road infrastructure is a publicly provided good as this project will be expected to service the wider public, with little prospects of profitability, making the government the best investor.

Table 7: Categorisation of Technologies for the Transport Sector

TECHNOLOGY	MARKET GOODS		NON-MARKET GOODS	
	Consumer	Capital	Publicly Provided	Other Non-Market
Battery Electric Vehicle	X			
Efficiency in Transport Sector				X
Integrated Public Transport			X	
Improving Road Infrastructure			X	
Solar charging stations	X			

1.5. EXCLUSION OF TECHNOLOGIES

The technologies *Passive House Design, Impact Windows and Doors*, and *Energy-Efficient Building Infrastructure Construction* from the building sector and *Integrated Public Transport* from the transport sector that were prioritized technologies in the Step 1 of the TNA Process, were not further assessed in this BAEF Report for the following reasons:

- There is limited political will to restructure the privately operated public transport system.
- The technologies identified as consumer goods are likely to have low diffusion due to the high capital cost that is inherent to the technology.
- Moreover, the technologies provide limited benefits over more affordable solutions currently being utilized.

2. WATER SECTOR TECHNOLOGIES

2.1. PRELIMINARY TARGETS FOR TECHNOLOGY TRANSFER AND DIFFUSION

As a broad overview, the targets for the six (6) prioritized water sector technologies are to:

i. introduce solar pumping systems to allow increased flexibility across water sector operations at the residential, commercial and community-scale;
ii. encourage increased levels of rainwater harvesting by providing a wider range of storage and treatment options for residential, commercial and community applications;
iii. promote the use of water-saving devices through increased education and awareness of the water-saving benefits of appliances and devices;
iv. aid the Water Utility in achieving greater levels of resilience through proactive risk management that addresses climate-proofing all major infrastructural investments;
v. promote stormwater reclamation and reuse through the construction of check dams and micro-catchments that will enable groundwater recharge, provide additional agriculture irrigation volumes, and encourage greater overall watershed management; and
vi. Introduce atmospheric water generators as an alternative to bottled water at the commercial scale, in private offices and government buildings in the education and health sectors.

Table 8 outlines indicative targets for nationwide technology diffusion.

Table 8: Quantitative Targets for Diffusion of Water Sector Technologies

TECHNOLOGY	SCALE OF DIFFUSION
Solar Pumping Systems	1,500 households (5% of the population) | 10 small to medium-sized farms
Rainwater Harvesting	3,000 households (10% of the population) | 10 community cisterns
Water-Saving Devices	1,500 households (5% of population) | 25% of private sector businesses
Climate-Proofing Assets	6 Reverse Osmosis Plants
Stormwater Reclamation and Reuse	Christian Valley watershed
Atmospheric Water Generators (Commercial)	50 private offices | 50 schools | 25 clinics and doctors' offices| 20 government offices

2.2. BARRIER ANALYSIS AND POSSIBLE ENABLING MEASURES FOR SOLAR PUMPING SYSTEMS

2.2.1. General Description of Solar Pumping Systems

Solar pumping systems substitute grid electric- and diesel-powered water pumps, for specialized equipment using power generated by solar photovoltaic (PV) panels. A complete system may vary in size and complexity, depending on the scale of operation and the end user's needs; where s*ome* or *all* power requirements for pumping are met by solar generation, or alternately power can be supplemented by backup generators or the grid. This facilitates a range of extraction, distribution and treatment processes that increase the supply of potable water for consumption and non-potable irrigation volumes.

Antigua and Barbuda's conditional adaptation targets to 2030 outlined in the INDCs, indicate that 100% of power demand for water generation, distribution and usage is to be met by off-grid renewable resources. In addition, the 2021 revision of the NDCs proposed the updated target to include, *100% of water supply infrastructure should be powered by their own grid-interactive renewable energy sources.* Thus, ensuring that water delivery is not unduly interrupted when the power grid is down, particularly following extreme climate events (GoAB 2015b). Residential and commercial properties can contribute to this achievement through the installation of on-demand pumping systems that utilize battery storage and a full array of direct current (DC) electronics, while resorts, private residential developments and the Utility can invest in systems where solar power is inverted to alternating current (AC) for continued use of standard equipment (WorldBank 2018). Solar pumps have also been incorporated into specialized membrane filtration systems that produce purified water through ultrafiltration (UF), nanofiltration (NP) and reverse osmosis (RO), promoting fully off-grid water treatment.

Solar water pumps are predominantly marketed in two (2) categories:

- *submersible* solar pumps, designed to fit well casings with a diameter of 4 inches (or larger), having maximum lift capacity up to 650-ft, and ideal for wells with standing water at a minimum depth of 20-ft. They can operate directly off of solar panels – limiting pumping to daylight hours, or on batteries – allowing for extended pumping hours (altE 2020a; SolarStore 2020a).
- *surface* solar pumps, designed for applications with shallow wells, ponds, streams, cisterns, and storage tanks, ideal for water supply less than 20-ft deep. They cannot lift the water over a significant vertical differential; however, they are apt for pushing water over 200-ft (altE 2020b; SolarStore 2020b).

The transfer and diffusion in Antigua and Barbuda will focus on *surface* solar pumps, to be used in residential, commercial – buildings and community reservoirs, and agricultural applications for distribution; and to a lesser extent, membrane filtration systems fitted with *submersible* solar pumps. Table 9 gives a breakdown of the range of recommended applications to be targeted locally, while Table 10 shows estimated retail costs of solar pumps and controllers. Solar PV panels are retailed locally at USD 330 OR XCD 885 and USD 375 OR XCD 1,020 for 260W and 315W respectively, and batteries are sold at USD 350 OR XCD 950 on the lower end and up to USD 1,750 OR XCD 4,755 on the higher.

Table 9: Target Solar Pumping Applications for the Antigua and Barbudan Market

TYPE	DESCRIPTION	APPLICATIONS
Potable	▪ Retrofit existing water distribution systems with *solar options* to replace or supplement grid power.	▪ Homes ▪ Schools ▪ Clinics, Hospitals
	▪ Design systems for water distribution from community reservoirs to homes/standpipes; OR to lift the water to elevated storage tanks.	▪ Community-scale water supply
Non-potable	▪ Design systems to extract and distribute raw surface or groundwater for use on the farm.	▪ Livestock watering ▪ Agriculture irrigation

Table 10: Landed Costs for Solar Pumps and Solar Filtration Units w/ Corresponding Applications

PUMP DETAILS	PUMPING APPLICATION			
	RESIDENTIAL	COMMERCIAL (BUILDING)	COMMERCIAL (COMMUNITY SCALE)	AGRICULTURE
Diaphragm Water Pump (direct PV) - 5.3gpm; 60psi - 12V DC @ USD 335 (XCD 910) - 24V DC @ USD 370 (XCD 1,005) - Controller USD 253 (XCD 685)	X (cisterns)			X (Irrigation ponds)
Diaphragm Water Pump (direct PV) - 3.0gpm; 40psi - 12V DC @ USD 210 (XCD 570) - 24V DC @ USD 298 (XCD 810) - Controller USD 253 (XCD 685)	X (drums/tanks)			
Solar Booster Pump (w/battery bank) - 4.5gpm; 65psi - 12V | 24V DC @ USD 1,315 (XCD 3,575) - 48V DC@ USD 1,450 (XCD 3,940) - Controller: USD 638 (XCD 1,735)	X (cisterns)	X (cisterns)		
Solar Booster Pump (w/battery bank) - 5,600gpd; 100psi - 48V DC@ USD 3,522 (XCD 9,570) - Controller: USD 638 (XCD 1,735)			X (Reservoir to standpipes)	

Solar Ultrafiltration Units - 5,000gpd - 12V DC @ USD 6,327 (XCD 17,010) - 10,000gpd - 12V | 24V DC @ USD 8,755 (XCD 23,790)		X (cisterns)		X (well | irrigation ponds)
Solar Reverse Osmosis Units - 10,000gpd - 12V | 24V DC @ USD 12,335 (XCD 33,515)				X (well | Irrigation ponds)

Solar pumps for residential and commercial applications can be implemented without the direct backing of a national entity, while solar filtration units for irrigation can be promoted as government-subsidized projects to build nationwide resilience within the agriculture sector. In both potable and non-potable applications end-users will bear the responsibility for installation, operation, and maintenance. In a phased introduction, systems will be marketed by five (5) major hardware suppliers, with a further introduction to smaller retailers in subsequent years.

2.2.2. Identification of Barriers for Solar Water Pumping

Solar pumping systems are categorized as Consumer Goods, targeting a wide cross-section of the local market including residential, commercial, and institutional end-users. The initial list of barriers presented to the TWG was reviewed and the resulting prioritization is detailed in

Table 11. Two (2) economic and financial and one (1) non-financial were ranked as critical / killer barriers. These were:

i.) High capital investment for system components [PV panels, pumps, accessories etc.], design and installation services.

ii.) Limited investment by retailers in stocking equipment [most equipment purchased on order].

iii.) Limited established retailers and package systems available on the island.

However, in follow up discussions with stakeholders it was decided that ii.) and iii.) would be better represented as a single barrier - *limited established retailers and package systems available on the island.*

Table 11: Prioritization of Barriers for Solar Pumping Systems

CATEGORIZATION OF BARRIERS – SOLAR PUMPING SYSTEMS					
CATEGORY	BARRIER	LEVEL OF IMPORTANCE			
		HIGH	MED	LOW	RANK
ECONOMIC & FINANCIAL	High initial capital investment for system components – panels, pump, accessories, and design/installation services	X			1
	Lack of financial incentives for private citizens [or community groups]		X		
	Low or uncertain return on investment for private citizens [inadequate data on cost vs. benefits]			X	
	Limited investment by retailers in stocking equipment [most equipment purchased on order] **	X			2
NON-FINANCIAL	Concerns around the robustness of external equipment during extreme weather events [roof or ground-mounted solar PV panels]			X	
	Low priority among certain income classes and/or social groups		X		
	Lack of consumer awareness of the immediate and longer-term benefits as a climate-smart (water) technology		X		
	Limited local capacity for installation and operation		X		
	Lack of financial incentives to develop local relevant skills			X	
	Limited established retailers and package systems on island**	X			2
	Low market penetration – perceived as a luxury investment for the wealthy		X		
	Uncertainty about the political will to promote technology		X		
	Lack of security for solar accessories [hardware]		X		

** Combined into a single barrier - *limited established retailers and package systems available on the island*

2.2.2.1. Economic and Financial Barriers and Measures

The barriers considered in this category included all the costs of technology components; *hardware* – PV panels, pumps etc., *software* – solar expertise and skills, and *orgware* – the network of solar retailers (IPCC 2000), associated with the diffusion of solar pumping systems. Stakeholders considered economic and financial barriers of medium to high importance, two of which were considered critical. Both barriers were decomposed into a single logical framework.

The Antiguan and Barbudan market is saturated with conventional alternating current (AC) centrifugal pumps, and to a lesser extent, diesel or gas-powered pumps. Residential and commercial consumers are required to make an initial investment for the purchase and installation of their systems, along with the continuous operation and maintenance costs. While there have been no studies commissioned to assess the willingness of local or regional consumers to transition to solar alternatives; local retailers and solar experts are satisfied that should the technology be introduced within ten per cent (10%) of the shelf price of the conventional counterpart, consumers would be sold based on the lower running operational costs. (GreenRevolution) began introducing solar pumps to the domestic market in the Turks and Caicos Islands and the Bahamas in 2011 and have documented an average three-year payback for their customers' initial investment. Retailers in the TWG suggested that package systems including the pump, PV panel, battery and accessories are better suited for residential consumers, while systems can be purchased in their constituent parts for larger-scale pumping operations.

Table 12 outlines the indicative market penetration prices for solar water pumps for the four (4) previously outlined applications.

Table 12: Market Penetration Price Levels for Solar Water Pumps

<table>
<tr><th rowspan="2">PUMP DETAILS | TARGET CUSTOMER BASE</th><th colspan="4">PUMPING APPLICATION</th></tr>
<tr><th>RESIDENTIAL</th><th>COMMERCIAL (BUILDING | INDUSTRY)</th><th>COMMERCIAL (COMMUNITY-SCALE)</th><th>AGRICULTURE</th></tr>
<tr><td>On-demand, extraction pumps for above ground tanks and rainwater barrels (direct PV)
First time, lower-income consumers</td><td>USD 500 (XCD 1,358)</td><td></td><td></td><td></td></tr>
<tr><td>Whole building distribution pump (w/battery bank)
Middle – higher-income consumers</td><td colspan="2">USD 2,045 (XCD 5,555)</td><td></td><td></td></tr>
<tr><td>Solar Ultrafiltration Units
First-time consumer with access to surface or groundwater source</td><td></td><td>USD 5,580 (XCD 15,160)</td><td></td><td>USD 9,300 (XCD 25,267)</td></tr>
<tr><td>Solar Reverse Osmosis Units
First-time consumer with access to surface or groundwater source</td><td></td><td></td><td></td><td>USD 12,335 (XCD 33,515)</td></tr>
</table>

Annex B details the combined Problem Tree of *causes* and *effects* for the critical economic and financial barriers –

i. *high initial capital investment for system components, design, and installation services*
ii. *limited established retailers and package systems available on the island.*

The Problem Tree outlines how limited solar water specialists and the lack of availability of small-scale solar water equipment in stores, result in overall lost economic opportunities for retailers and technicians and no benefits to water users. While the Objective Tree highlights *measures* that will result in increased social and economic *benefits*. Table 13 provides a summary of the measures discussed in TWGs.

Table 13: Measures for Barriers: Solar Pumping Systems

CRITICAL BARRIER	ROOT CAUSES	ENABLING MEASURES
High initial capital investment for system components, design, and installation services.	▪ High consultancy fees for solar [energy] specialists, a limited number of whom focus on solar water solutions ▪ High labour costs for system installation ▪ Limited local capacity for installation and maintenance ▪ No local manufacturers or suppliers of solar pumping equipment ▪ Customers must absorb costs for import duties and taxes	▪ Establish specialist cooperatives [solar energy specialists and water equipment service providers] to investigate and promote the expansion of commercial interests to include solar water solutions ▪ Provide access to public sector solar specialists – *Pro Bono* or at minimum market rate – to advise interested residents on sizing and design ▪ Provide tax exemptions and access to funds (e.g., through the Entrepreneurial Development Programme) to incentivize local suppliers to invest in solar pumping business opportunities, such as partnering with overseas manufacturers/suppliers and assembling equipment locally ▪ Facilitate upskilling opportunities for local plumbing and electrical technicians to increase local capacity and availability of technical skills
Limited established retailers and package systems on the island	▪ Limited number of local solar retailers ▪ Small scale, package systems not made available in-store [off the shelf] ▪ Replacement equipment and parts are not readily available	▪ Incentivize local retailers to purchase, stock and market small scale, package solar pumping systems for residential and commercial applications, by zero-rating import duties and taxes for all solar equipment and accessories ▪ Facilitate quick repairs and limited system downtime by having adequate stock of essential replacement parts and a reliable network of technicians available on the island [by partnering with regional suppliers/manufacturers]

2.2.2.2. Non-Financial Barriers and Measures

Nine (9) non-financial barriers were considered for this technology, the majority of which were ranked *medium* to *high* in their levels of importance. While it was the consensus of the TWG to decompose the most critical non-financial barrier based on its economic implications, it was also considered worthwhile to flesh out some of the measures that might become useful in overcoming the remaining non-financial barriers.

Table 14 below summarizes the TWG discussions.

Table 14: Summary of TWG Discussion on Non-Financial Barriers and Measures: Solar Pumping Systems

<table>
<tr><th>NON-FINANCIAL BARRIERS</th><th>POSSIBLE MEASURES</th></tr>
<tr><td>Consumer concerns about [lack of trust in] the robustness of external equipment – roof or ground-mounted solar PV panels – during extreme weather events;</td><td>Install external units with mounts and clips rated for a minimum of Category 4 tropical weather systems and explore mounting bracket options that are easily collapsible that will allow solar panels to be removed and stored when necessary;

Develop public service announcements (PSAs) that include removal and storage of solar equipment as a part of residential and commercial hurricane preparedness plans;</td></tr>
<tr><td>Low priority among certain income classes and/or social groups;</td><td>Promote solar renewables as a class inclusive technology by marketing a range of equipment and conduct widescale educational campaigns that specifically target socially vulnerable groups, lower-income households and farmers:

- smaller systems to circulate and pump water from 55-gallon drums and 1000-gallons storage tanks to a single tap;
- medium-sized systems to replace cisterns pumps capable of circulating water throughout a building or providing water on-demand for farming operations; and
- larger systems that lift water from a distribution line to a storage tank</td></tr>
<tr><td>Low market penetration – perceived as a luxury investment for the wealthy;</td><td rowspan="2">Develop education and awareness campaigns that highlight the benefits of grid-independent water pumps that lower household energy costs and allow for quick on-streaming of water distribution following extreme weather events when Utility water is not yet available;

Partner with the SIRF Fund and/or local credit unions to provide concessionary loans for the purchase of solar water pumping equipment</td></tr>
<tr><td>Lack of consumer awareness of the immediate and longer-term benefits as solar renewable equipment a climate-smart (water) technology;</td></tr>
<tr><td>Uncertainty about the political will to promote technology</td><td>Work with government agencies to promote and incentivize the purchase of solar water pumps;</td></tr>
</table>

2.3. BARRIER ANALYSIS AND POSSIBLE ENABLING MEASURES FOR RAINWATER HARVESTING

2.3.1. General Description of Rainwater Harvesting

Rainwater harvesting (RWH) is the diversion, capture, storage, and treatment of precipitation for potable and non-potable uses. While systems vary in size and complexity, they typically include catchment surface, transport, storage, treatment, and distribution. There are four classifications of RWH, *occasional*, where a day's water supply is stored in small containers; *intermittent*, where the water is harvested during rainy periods and it meets most water demands; *partial*, where rainwater is used throughout the year, but the harvest is not enough for all domestic demands; and *full*, when all water needs are met by the rainwater harvest since there is no alternative water source. Systems across Antigua and Barbuda are typically designed to meet the needs of *occasional* and *partial* users[1].

Currently, rainwater harvesting is supported by the Building Code (1993) and Physical Planning Act (2003), and the Development Control Authority (DCA) guidelines dictate that all newly constructed buildings must include rainwater capture and storage for the architectural plans to be approved. However, further adoption would be encouraged if additional cost-effective storage options, that rival reinforced concrete in-ground cisterns, were available on the local market. Existing applications could be improved by including adequate treatment for residential and commercial systems. Routinely cleaning rooftops, gutters, and storage tanks, along with simple chlorination, cartridge filtration and installing point-of-use ultraviolet sterilization units are the most cost-effective ways for any household to ensure the harvested water is safe for consumption. In addition, providing feasible storage options that specifically target the agricultural sector will also be beneficial.

At present, there are primarily two (2) types of above-ground storage tanks used in residential applications:

i.) Polyethylene barrels, 55 and 77 US gallons open-top, available used from USD 25 – USD 50 OR XCD 67 – XCD 135. Barrels are imported with cargo and sold used.

ii.) Polyethylene *Tuff Tanks and CKD Tanks*, 450, 600 and 1,000 US gallons, closed top, FDA food grade, available new up to USD 450 OR XCD 1,210 – with an additional cost of approximately USD 500 OR XCD 1,350 to construct the tank foundation. Tanks are imported from Rotoplastics Trinidad Ltd. and are readily available at local distributors.

The primary in-ground storage option is reinforced concrete cisterns that can be sized to any desired capacity depending on the needs of the user. The estimated cost for a 10,000 US gallon capacity is between USD 12.5k - USD 18k OR XCD 33k – XCD 48k. Table 15 shows three (3) of the storage options discussed during consultations:

Table 15: Unconventional Rainwater Storage Options

TYPE	SPECIFICATIONS AND COST	COMMENTS
Rainwater Pillow[2,3]	▪ Above ground ▪ Materials: PVC, Polyethylene (PE), Thermoplastic polyurethane (TPU) ▪ Size: 5,000 gallons	▪ Suitable for beneath homes elevated on columns and farms [in trailer containers]

1 Classifications developed for the 'Sustainable Sanitation and Water Management Toolbox'.
2 Tanks for Less. Water Tanks and Rain Harvesting Equipment. "Fol-da-Tank". https://www.tanksforless.com/c/366/fol-da-tank
3 Chongqing Mola Technology CO., Ltd. The Best Solution for Water Storage. Fuel Storage. "Drinking Water." http://molatank.quality.chinacsw.com/c1423314-drinking-water-tank

TYPE	SPECIFICATIONS AND COST	COMMENTS
	▪ Completely collapsible, mobile, minimal installation ▪ Cost: USD 3,500 | XCD 9,510 ▪ Maintenance: Negligible	
IBC Totes 	▪ Above ground ▪ Materials: PVC ▪ Size: 330 gallons, stackable ▪ Installed on concrete block (no masonry work needed), mobile ▪ Cost: USD 250 |XCD 679 ▪ Maintenance: Negligible ***food-grade tanks available*	▪ Tanks are available in both food grade and commercial non-food grade quality
Plastered Tire Cisterns[4,5] 	▪ In-surface ▪ Materials: Used tires, earth. Backfill, wire mesh/rebar, plywood concrete (plaster) ▪ Size: *Any* ▪ Labour intensive ▪ Cost: USD 6,700 | XCD 18,203 (7,500 gallons) ▪ Maintenance: USD 150 | XCD 400 (annual cleaning)	

According to the "Antigua and Barbuda 2011 Population and Housing Census | Book of Statistical Tables I" a total of 2,579 households are dependent on public standpipes, and an additional 53 households are dependent on public tanks (GoAB 2014). These are predominantly lower-income households or families living below the poverty line that have no access to Utility supply on their premises and, also have limited or very little capacity to harvest and store adequate volumes of rainwater for daily use. Improved diffusion of residential rainwater harvesting systems can aim to target 3,000 households across Antigua and Barbuda, enabling them to add or increase at-home storage capacity. While, at the community scale, diffusion will target the rehabilitation of ten (10) community cisterns with capacities of 50,000 to 125,000 U.S. gallons.

2.3.2. Identification of Barriers for Rainwater Harvesting

Residential and commercial-scale rainwater harvesting systems are Market | Consumer Goods, targeting residential, commercial, and institutional water users. The components of a rainwater harvesting system are privately procured from manufacturers and suppliers on the local, regional,

[4] Pushard, Doug. 2014. "Comparing Rainwater Storage Options". Harvest H2O. http://www.harvesth2o.com/rainwaterstorage.shtml
[5] Long Way Home. 2004. "Cisterns". https://www.lwhome.org/designsconstruction

and international markets and utilized by users at the end of the supply chain. Community-scale systems may however be considered Market | Capital Goods wherever they are utilized to support communal business activities. Community development organizations across Antigua and Barbuda hoping to procure larger scale RWH systems, envision using them for agriculture, small-scale manufacturing, and eco-tourism activities. Demand for equipment is influenced by consumer awareness, while the types of equipment chosen may be influenced by marketing promotions and the spending capacity of end-users.

The initial list of barriers presented to the TWG was reviewed and the resulting prioritization is shown in Table 16. Two (2) economic and financial barriers were ranked as critical / killer, along with two (2) non-financial barriers. These were:

i.) Cost and availability of unconventional rainwater storage options;
ii.) High costs to refurbish community reservoirs or install community tanks and catchments;
iii.) Limited established [or fully functional] community groups/NGOs to spearhead reservoir refurbishment and RWH system maintenance; and
iv.) No incentives to encourage pairing with complementary climate-smart [water] technologies, such as solar pumping systems.

During one-to-one consultations, stakeholders agreed to combine the two barriers associated with community-scale rainwater harvesting systems, concluding that the lack of ownership and technical capacity at the community level would in turn influence cost. Hence, barriers ii.) and iii.) were decomposed in a single logical framework.

Table 16: Prioritization of Barriers for Rainwater Harvesting

CATEGORIZATION OF BARRIERS – RAINWATER HARVESTING (RWH)					
CATEGORY	BARRIER	LEVEL OF IMPORTANCE			
		HIGH	MED	LOW	RANK
ECONOMIC & FINANCIAL	High cost of reinforced concrete in-ground cisterns (preferred option) for lower-income residential properties		X		
	Uncertain costs [and limited availability] for unconventional in-ground and above-ground storage options	X			1
	High costs to refurbish community reservoirs or install community tanks [and catchments]	X			2
	Aesthetics of unconventional above ground storage			X	
	Very little commitment by landlords to provide storage for low-income rental properties		X		
	Portability of renter-owned storage options [ability to move storage from rental to rental]		X		
	Challenges installing storage (or additional volume) on standard residential plots after construction			X	

CATEGORIZATION OF BARRIERS – RAINWATER HARVESTING (RWH)					
CATEGORY	BARRIER	LEVEL OF IMPORTANCE			
		HIGH	MED	LOW	RANK
NON-FINANCIAL	Limited technical capacity for sizing storage [to ensure adequate volume to meet occupancy needs]		X		
	Little to no DCA monitoring and/or inspection for compliance to architectural plans during construction			X	
	Limited technical capacity for designing/testing new innovative options		X		
	Lack of incentives for farmers and socially vulnerable groups to acquire RWH systems		X		
	No incentives to encourage pairing with complementary climate-smart [water] technologies [such as solar pumping systems]	X			4
	Limited established [or fully functional] community groups/ NGOs to spearhead reservoir refurbishment and RWH maintenance	X			2

2.3.2.1. Economic and Financial Barriers and Measures

The economic and financial barriers represent the overall costs for end-users to procure and install the *storage* component of rainwater harvesting systems. The three (3) barriers were ranked medium to high in their level of importance, as stakeholders believed that cost was the single most significant factor that influenced the type of rainwater harvesting system Antiguans and Barbudans installed. The TWG collectively concluded that in-ground concrete cisterns would always be the preferred choice; with Antiguans favouring cisterns incorporated into the building's foundation, and Barbudans being partial to cisterns constructed separately on the premises.

A detailed Problem Tree (developed for the – *cost and availability of unconventional rainwater storage options)* outlines how the limited range of products marketed by local retailers and the unavailability of financing to develop new innovative local options, result in lost economic opportunities and increased hardship for the lower-income demographic and renters. While the Objective Tree highlights *measures* outlined to achieve increased water security at the residential and commercial levels.

A Problem Tree was also developed for the – *high costs to refurbish community reservoirs or install community tanks and catchments*, highlighting how the lack of pooled community funds and the inability to successfully obtain grants or loans, results in lower levels of community water security and lost opportunities for revenue generation. The corresponding Objective Tree highlights the *measures* identified to increase water security and complementary co-benefits at the community level through increased communal water storage. The Problem and Objective Trees for rainwater harvesting are shown in Annex C.

Table 17 below provides a combined summary of the measures for the two critical economic and financial barriers.

Table 17: Measures for Financial Barriers: Rainwater Harvesting

CRITICAL BARRIER	ROOT CAUSES	ENABLING MEASURES
Cost and availability of unconventional rainwater storage options	▪ Uncertain costs for durable, high volume sub-surface and above ground rainwater storage tanks ▪ Limited options available on market for consumers to compare ▪ Retailers are not willing to import, stock and market unfamiliar/alternative storage options ▪ Low interest in designing and testing cost-effective storage using locally available raw materials [e.g., plastered-tire cisterns] ▪ Limited available financing options for small-scale entrepreneurs interested in demonstrating alternative storage options	▪ Provide financial incentives for retailers to import, market-test, stock and retail a wider range of rainwater storage options ▪ Promote a range [max. 5] of *new* storage options and encourage consumers to examine and compare costs and applicability [versus concrete in-ground cisterns] ▪ Stimulate local interest in designing and demonstrating *novel* low costs storage by increasing access to financing and lowering investment risks
High costs to refurbish community reservoirs or install community tanks and catchments	▪ Lack of a source of income generated by the community that can be designated for refurbishment projects ▪ Limited availability and/or willingness of skilled workmen keen to volunteer labour for renovations ▪ Lack of technical capacity within the community/community groups [NGOs] to plan, coordinate and manage refurbishments efforts ▪ Limited capacity to write competitive grant proposals that target advertised funding ▪ Limited awareness of, and ability to capitalize on various financing channels [loan facilities]	▪ Target donations [from the business community, overseas residents, local government etc.] to accumulate seed funds to jumpstart refurbishment projects ▪ Organize community workdays to elicit volunteer labour from community residents [and the willing public] to assist with renovations ▪ Hire skilled labour where necessary ▪ Strengthen technical capacity within community groups for planning/design, project coordination and financial management ▪ Strengthen proposal writing capacity by seeking training opportunities for community NGO members ▪ Improve collaboration between community NGOs and schools, and utilize the

CRITICAL BARRIER	ROOT CAUSES	ENABLING MEASURES
		school as a channel for executing small scale project activities ▪ Create opportunities for income generation in the early phases of the refurbishment project to promote various sources of income [thus limiting reliance on free money]

2.3.2.2. Non-Financial Barriers and Measures

A list of ten (10) non-financial barriers to rainwater harvesting was presented, of which one (1) was considered critical to improved deployment *(see* Table 18*)*. Of the remaining barriers, stakeholders identified an additional four (4) that should be monitored closely and were keen to share their views on how these might be addressed in the future. Table 18 below summarizes stakeholder suggestions for mitigating them:

Table 18: Summary of Stakeholder Discussion on Non-Financial Barriers and Measures: Rainwater Harvesting

NON-FINANCIAL BARRIERS	POSSIBLE MEASURES
Very little commitment by landlords to provide storage for low-income rental properties;	Enforce the legislation which stipulates that all properties must have adequate rainwater storage, compelling landlords to make provision for storage before renting their properties In low-income housing, where the installation of storage will result in higher rental prices, encourage landlords to provide at the minimum – guttering around the roof, downspouts and a pad for a storage tank/s – thus giving renters the option of acquiring their storage. Landlords unable to readily make significant capital investments in their low-income properties are now able to access low-interest loans from the Sustainable Island Resource Framework (SIRF) Fund, a revolving fund specifically set up to finance climate change adaptation and mitigation interventions. Similarly, gainfully employed renters can utilize the funding from the SIRF Fund to purchase potable water storage Provide recourse for renters by giving them a *safe* procedure for reporting negligent landlords, and provide them with information about the appropriate channel [person, department or government agency] where complaints might be lodged [stakeholders suggested that this might fall under the mandate of the Ministry of Social Transformation]
Portability of renter-owned storage options [ability to move storage from rental to rental];	Promote the range of easily portable storage options, using advertisements that target renters
Limited technical capacity for sizing storage [to ensure the installed volume is adequate to meet occupancy needs];	Design and implement education, awareness and training opportunities for homeowners, draughtsmen, and builders; enabling them to successfully size rainwater storage based on the size of property and occupancy Encourage property owners to consider adding storage when occupancy increases

NON-FINANCIAL BARRIERS	POSSIBLE MEASURES
	Increase human resource capacity within the DCA to ensure that adequate storage is included on architectural drawings and make follow-up checks to confirm that builders adhere to approved plans
Lack of incentives for farmers and socially vulnerable groups to acquire the RWH system.	Establish programmes through the Agriculture Extension Division that provide incentives for small scale farming operations to acquire storage. E.g., providing access to low-interest financing for farmers to procure and install storage Establish similar initiatives through the Community Development Division for socially vulnerable groups to acquire storage for their homes

Following consultations with property owners of low-income rentals, it should be acknowledged that they generally have significant ongoing financial constraints owing to the unreliable remittance of rental payments and lack of care for the property by renters. For instance, a property owner offering an older 2-bedroom wooden house for XCD 500 (USD 185) per calendar month, may reliably receive eight (8) or nine (9) month's rent in total over a consecutive twelve (12) month period. Annual upkeep of this house – changing rotted out floor and sideboards and replacing fixtures etc. – may cost the owner on average XCD 2,000 (USD 735) for materials and labour. Hence, while the landlord might be willing to address routine maintenance, there would be very little incentive to make a major investment knowing that it is unlikely that it will be covered by the rental payments. Stakeholders agreed that both landlords and renters should be willing co-contributors to overcoming the issue of inadequate storage

To address the critical/killer barrier, Annex C below details the Problem Tree outlining how the absence of national programmes that educate the public about linkages between climate-smart technologies, often result in harvested water being underused or wasted due to accessibility constraints. While the Objective Tree highlights *measures* to overcome these root causes and the resulting *benefits*. Table 19 provides a summary of the measures.

Table 19: Measures for Non-Financial Barriers: Rainwater Harvesting

CRITICAL BARRIER	ROOT CAUSES	ENABLING MEASURES
No incentives that encourage pairing RWH with *solar pumping systems*	▪ Rainwater harvesting is not promoted in tandem *solar pumping systems* ▪ Lack of awareness about the co-benefits [of pairing technologies] for water users ▪ Limited financial incentives for purchasing *solar pumping equipment*	▪ Promote *solar pumping systems* as a complementary technology to rainwater harvesting for residential and community storage systems ▪ Increase awareness about potential uses of *solar pumping* along the rainwater harvesting chain – specifically treatment and distribution ▪ Create a program/s that provide financial incentives to

		individuals and groups interested in acquiring *solar pumping equipment*

While the focus was given to pairing rainwater harvesting with solar pumping systems, stakeholders acknowledged that similar couplings can be made with other technologies, e.g., pairing RWH with water-saving devices to promote conservation and reduce wastage.

2.4. BARRIER ANALYSIS AND POSSIBLE ENABLING MEASURES FOR WATER SAVING DEVICES

2.4.1. General Description of Water Saving Devices (Water Savers)

In modern society, water-efficient appliances, fixtures, and devices, are used to augment in-home conservation efforts. These water savers have a variety of commercial and residential applications within buildings, landscaping, pools, and factories. In the Antiguan and Barbudan context, the TNA Project will focus on widescale diffusion in commercial buildings. Table 20 shows the four (4) target water-saving devices and estimated reductions for an average household.

Table 20: Estimated Water Savings for a 4-Person Household[6]

DEVICE	ESTIMATED CONSUMPTION	WATER-SAVING DEVICES	ANNUAL % SAVINGS
Aerators	▪ Faucet: 2.2gpm ▪ Household: 9,800g/yr	▪ Faucet: <1.5gpm ▪ Household: ~6,500g/yr	~30%
Shower Heads	▪ 1990s: >5gpm ▪ 2000s: 2.5gpm	▪ Low flow: <1.8gpm	~30%
Toilets	▪ 1990s: 3.6gpf ▪ Household: 26,000g/yr	▪ Dual flush: 1.1gpf ▪ High Efficiency: 1.3gpf ▪ Ultra-low-flush: 1.6gpf ▪ Household: ~11,000g/yr	~55%
Washing Machines	▪ Standard: 40-45g/load ▪ Household: 12,000g/yr **Water Factor: 10*	▪ High efficiency: 12-25g/load ▪ Household: ~4,500g/yr **Water Factor: 8*	~60%

Installation of new low-flow faucets, showerheads, toilets, and household appliances, or retrofitting older plumbing with aerators, high-efficiency check valves and flow restrictors and regulators will assist in increasing water savings in buildings. However, water savers are most effective when combined with improved practice by conscientious consumers and can help to reduce water usage by up to 70%.[7] According to HomeWaterWorks (2018), the highest in-home water usage includes kitchen (15.7%), bathroom (18.6%), laundry (21.7%) and leaks (13.7%). Hence, consumers must

[6] Home Water Works, *A Project for the Alliance for Water Efficiency*, https://www.home-water-works.org/indoor-use
[7] Akruthi Enviro Solutions Pvt. Ltd., http://neoakruthi.com/blog/how-to-save-water-at-home.html

understand these trends and prioritize changes based on these high usage areas, for the successful adoption of this technology.[8]

A wide range of water-efficient fixtures and appliances are available in several hardware stores across Antigua and Barbuda – some of which can be identified by the *water-saving* green tag. Budgetary constraints typically lead property owners to determine how much they can afford to invest; however, it should be noted that a range of high-efficiency devices are offered at costs only fractionally more expensive than their less efficient counterparts. Price comparison is shown in Table 21, and the consumer may also incur an additional cost of USD 30/hr OR XCD 80/hr for hiring a plumbing technician for installation.

Table 21: Average Cost of WSDs vs. Conventional Alternatives

DEVICE	WSD COST (USD$)	CONVENTIONAL DEVICE (UDS$)
Aerators	7	N/A
Shower Heads	18	10
Toilets	365	273
Washing Machines	925	560

In a 4-person household, with average monthly consumption of 8,000 imperial gallons and a bill of USD 105 or XCD 285 per month before the installation of the water savers, the cost savings to the customer would be approximately 43% if the four devices in Table 21 are installed – and there are no significant changes in water use patterns. This translates to an average monthly consumption of ~4,500 gallons and a bill of USD 40 or XCD 110. The savings by volume would be particularly important to consumers who primarily use harvested/stored water, as this would result in their stores lasting for longer periods.

2.4.2. Identification of Barriers for Water Saving Devices

Water-Saving Devices are Market | Consumer Goods, targeting residential, commercial, and institutional water users. They are privately procured from existing suppliers on the local and international markets and installed and operated by any user at the end of the supply chain.

The initial list of barriers presented to the TWG was reviewed and the resulting prioritization is shown below in Table 22. None of the four (4) economic and financial barriers was ranked as critical / killer, while three (3) of the non-financial barriers attained a high ranking. These were:

[8] Home Water Works, *A Project for the Alliance for Water Efficiency,* https://www.home-water-works.org/indoor-use

i.) Limited education and awareness about the water-saving benefits of household appliances/devices

ii.) Lack of complementary behaviour change in water users [related to water consumption and conservation]

iii.) Homeowners lack the ability to analyse and understand water use trends within the home

Stakeholder discussions regarding effective adoption of water savers across the State primarily centred around education and corresponding behaviour change. During the stakeholder briefing meeting it was decided that since this was the common thread that linked the three critical barriers, they could be all encompassed in – low education and awareness about the water-saving benefits of appliances/devices and fleshed out in the logical framework analysis. While Antiguans and Barbudans may inadvertently procure and install water-saving devices, the motivation driving their purchases seem primarily related to market availability, aesthetic preferences, and disposable income. In addition, those who primarily use harvested/stored water will also be motivated to change because the stores will last longer. It was the consensus among stakeholders that property owners would not deliberately incur the cost to replace fixtures that are still in good working condition with high-efficiency alternatives, even if they are knowledgeable about the impacts of climate change. In most cases, a homeowner will choose from the devices available in their preferred store/s and make a purchase based on aesthetics, capacity, and price. Further, lower-income earners will most often be primarily guided by the price when choosing to purchase a device or fixture.

Table 22: Prioritization of Barriers for Water Saving Devices

CATEGORIZATION OF BARRIERS – WATER SAVERS					
CATEGORY	BARRIER	LEVEL OF IMPORTANCE			
		HIGH	MED	LOW	RANK
ECONOMIC & FINANCIAL	Cost of retrofitting homes/businesses with water-efficient devices			X	
	Uncertain return on investment for businesses and commercial buildings		X		
	Uncertain return on investment for low-income households		X		
	Lesser efficient models are marketed at a lower price			X	
NON-FINANCIAL	No nationally established efficiency standards for importation of appliances and fittings		X		
	Lack of complementary behaviour change in water users [related to water consumption and conservation]	X			2
	Limited education and awareness about the water-saving benefits of household appliances/devices	X			1

CATEGORIZATION OF BARRIERS – WATER SAVERS					
CATEGORY	BARRIER	LEVEL OF IMPORTANCE			
		HIGH	MED	LOW	RANK
	Homeowners lack the ability to analyse/understand water use trends within the home	X			2
	Retail sales[persons] are not focused on selling appliances based on efficiency		X		

2.4.2.1. Economic and Financial Barriers and Measures

The economic and financial barriers identified focused on the costs of procuring and installing water savers. However, they were ranked low to medium in their level of importance, as stakeholders believed that while disposable finances would influence the purchasing patterns, socio-cultural factors were more significant within the Antiguan and Barbudan context. Customers who live in areas with no network coverage, depend on cisterns and/or purchase water from bulk suppliers, have been transitioning to water savers to conserve their limited supplies. The two medium barriers relating to return on investment could also be addressed through education and would therefore equip other consumers with the knowledge to make similar changes.

2.4.2.2. Non-Financial Barriers and Measures

Five (5) non-financial barriers were considered for this technology, of which three (3) were considered critical to adoption and selected to be decomposed by the TWGs *(see* Table 23*)*. The two (2) remaining barriers were ranked *medium* and the following measures in Table 23 were suggested for mitigating them:

Table 23: Summary of Stakeholder Discussions Non-Financial Barriers and Measures – Water Saving Devices

NON-FINANCIAL BARRIERS	POSSIBLE MEASURES
No nationally established efficiency standards for importation of appliances and fittings	Capitalize on the government's intention to develop efficiency standards for the importation of all vehicles and appliances, as stated in the *Conditional Mitigation Targets* of Antigua and Barbuda's INDC Targets to 2030, to ensure that water use related fittings, fixtures and appliances are included Collaborate with the Bureau of Standards to develop and adopt water efficiency standards for Antigua and Barbuda Develop a plan to phase out the sale of low-efficiency devices and appliances;
Retail salespersons are not focused on selling appliances based on efficiency (i.e., volumes of water saved)	Partner with the Chamber of Commerce and other civil society / private sector organizations to provide training for retail sales personnel Develop or adopt a water efficiency symbol – at the national or regional (OECS) level, that can be used to quickly identify water-efficient appliances in department stores.

The Problem Tree in Annex D details the *causes* and *effects* of the critical non-financial barrier – *low education and awareness about the water-saving benefits of household appliances and devices*. It outlines how an overall limited understanding of holistic water usage and conservation along with traditional consumer purchasing influences, result in lost opportunities to promote a cultural shift towards zero-wastage and cause greater demands on the Utility for increased volumes of potable water. While the Objective Tree highlights the *measures* that can be employed to ensure full and effective technology diffusion.

Table 24 below provides a summary of the measures.

Table 24: Measures for Non-financial Barriers: Water Saving Devices

CRITICAL BARRIER	ROOT CAUSES	ENABLING MEASURES
Low awareness about the water-saving benefits of WSDs	▪ Little correlation made between the choice of device and saving [in terms of volumes consumed] ▪ Harvest or stored volumes are not maximized which leads to bulk water purchases ▪ Limited ability to analyse water use trends ▪ Lack of focus on addressing practice change in high usage areas around the property ▪ Low priority given to choosing devices based on volumes of water saved, with purchases influenced by aesthetics, size and cost	▪ Develop a water efficiency labelling system that can be utilized to rate devices based on volumes of water saved, and partner with retailers to use labelling in store ▪ Design a charting system that shows indicative uses of water around the property, coupled with water conservation tips ▪ Develop water efficiency standards for devices and work with the authorities [and Bureau of Standards] to promote a system of tax breaks for imports based on water savings

2.5. BARRIER ANALYSIS AND POSSIBLE ENABLING MEASURES FOR CLIMATE-PROOFING ASSETS

2.5.1. General Description of Climate-Proofing Assets

Resilient infrastructure can significantly reduce but may not fully eliminate climate-related disruptions to APUA's service. Climate-proofing can improve the reliability of service and increase asset life, by addressing the extent to which climate change translates into risks to infrastructure. The critical characteristic of climate-resilient infrastructure is that it is *planned*, *designed*, *built* and *operated* in a way that anticipates, prepares for, and adapts to changing climate conditions (OECD 2018). For critical water sector assets, it involves assessing *exposure* and *vulnerability*, developing risk management plans and systematically de-risking (building resilience in) the Utility. Thus, enabling it to withstand, respond to, and recover rapidly from disruptions caused by extreme climate conditions. Climate-proofing is a continual process throughout the life of the asset (ADB 2016; OECD 2018).

Comprehensive and proactive risk management requires making trade-offs between risk minimization and cost – particularly when it would be more expensive and technically challenging for APUA to prepare for events that are very unlikely to occur. While resilience indicates that major risks have been considered and managed; thus, achieving an acceptable level of performance based on the available information. It also assumes that the capacities to withstand and recover from shocks are in place (OECD 2014, 2018). A 2019 project funded by the Caribbean Development Bank (CDB) as part of the ACP-EU-CDB NDRM[9] assessed the existing climate-related vulnerabilities in APUA's infrastructure and presented an *Investment Plan for climate-resilient water supply services.* The TNA can outline a plan to implement the key activities relating to the existing physical assets. Comprehensive de-risking must address every stage of the water supply process. Hence, managing physical assets – desalination facilities, pump stations, pipelines etc. – will be part of a more globally dynamic process within APUA's overall operations.

According to HRW (2019), climate-smart asset management for APUA will include:

- Protecting desalination facilities from storm surges and hurricane-force winds, with attention given to all related infrastructure, intake and outfalls, reverse osmosis plant, building, electricals etc.;
- Relocating pipelines to accommodate storm surges, flooding and/or erosion; and
- Moving pumps and/or pumping stations to higher elevations.

The timeline for complete de-risking of the APUA is estimated at a minimum of five (5) years depending on the availability of funds.

2.5.2. Identification of Barriers for Climate-Proofing Assets

Climate-Proofing Assets is categorized as a Non-Market | Publicly Provided Good, which addresses strengthening nationally owned infrastructure and the complementary services provided – at a cost – to all residents of Antiguan and Barbuda. The infrastructural assets are provided through large investments approved at the government level, procured through national/international tenders or public-private partnerships, and utilized to provide reliable water supply to consumers.

The list of barriers presented to the TWG was reviewed and the resulting prioritization is shown in

[9] African Caribbean Pacific – European Union – Caribbean Development Bank National Disaster Risk Management

Table 25. Two (2) economic and financial and one (1) non-financial were ranked as critical / killer barriers. These were:

i.) High cost of the phased implementation of the *R*isk *M*anagement *P*lan.

ii.) Uncertain access to international donors/lenders for relevant finances.

iii.) Increased levels of public concern about the lengthy project timeline.

During the stakeholder briefing meeting, it was decided that the two financial barriers would be better represented as a single barrier – *high cost for the phased implementation of the Risk Management Plan with uncertain access to finances*, owing to the ongoing financial constraints experienced by the Utility.

2.5.2.1. Economic and Financial Barriers and Measures

The economic and financial barriers identified included design and implementation costs for all the activities and processes involved in de-risking APUA's Water Division. While, two (2) financial barriers were considered critical, the three (3) additional barriers were given a *medium* level of importance, and therefore may also need to be factored into ensuring long term sustainability of technology transfer. Stakeholders suggested the following general measures that could be explored in the future:

- The presumed high design costs to carry out a comprehensive vulnerability assessment and develop a risk management plan was owing to the assumption that the task would likely be outsourced to a regional or international consulting company. However, this was not considered prohibitive since stakeholders were certain that local consultants and APUA's technical staff – under the guidance of an experienced technical expert – would be able to complete the task at a reduced cost. This was strengthened by confirmation that in recent years several studies were completed, which would provide the baseline data for developing a comprehensive risk management plan.
- Similarly, while acknowledging that the current financial status of the Utility is dire, stakeholders highlighted that investing in risk management is unavoidable. A failure to spend on de-risking will result in greater spending on reactive maintenance, repairs and replacement of assets after a severe climate event. Hence, the Utility must consider the trade-offs between risk minimization and cost.
- Finally, stakeholders considered tariff reform as a political – rather than economic – issue that would only be addressed if the sitting government is willing to deal with the political fallout that might ensue when the new rates are introduced. Phased, incremental tariff increases, accompanied by a proactive education and awareness campaign, could be one approach to overcome this barrier.

Table 25: Prioritization of Barriers for Climate-Proofing Assets

CATEGORIZATION OF BARRIERS – CLIMATE-PROOFING ASSETS					
CATEGORY	BARRIER	LEVEL OF IMPORTANCE			
		HIGH	MED	LOW	RANK
ECONOMIC & FINANCIAL	High cost of designing a comprehensive risk management plan for Utility		X		
	High costs of the phased implementation of [risk management] Plan**	X			1
	Additional financial burden on an already indebted Utility		X		
	Uncertain access to international donors/lenders for relevant finances**	X			1
	Unwillingness by the GoAB to restructure tariffs to offset costs		X		
NON-FINANCIAL	Political will to prioritize proactive management of Utility		X		
	Revenue loss [by Utility] during service interruptions		X		
	Lack of technical capacity on-ground for design and implementation			X	
	Lack of coordination across ministries and government departments leading to hiccups, delays and longer project timeline		X		
	Lack of transparency – financial and non-financial		X		
	Limited public buy-in			X	
	Inadequate information and/or misinformation about the process		X		
	Increased public concerns about the length of a project timeline	X			3
	Process of acquiring new and/or permission to build on or traverse private lands			X	
	Loss of beach access by locals and visiting tourists [due to construction of seawalls/embankments to protect RO plants]			X	
	Loss of business due to prolonged civil works			X	

**Combined into a single barrier – *"High cost for the phased implementation of the Risk Management Plan with uncertain access to finances"*

Annex F shows the detailed Problem Tree of *causes* and *effects* for – *High cost for the phased implementation of the Risk Management Plan with uncertain access to finances,* outlining how the Water Utility's inadequate revenue generation coupled with the government's limited capacity to co-finance risk management activities would result in greater impacts on national water security. While the Objective Tree highlights *measures* to overcome those root causes and the resulting *benefits* for the wider Antiguan and Barbudan society. It should be noted that while the government contributes to large scale infrastructural improvements, the Utility should be a self-sustaining entity that not only covers all its operation and maintenance costs. At present APUA's Water Division is unable to meet these financial obligations. The full range of measures is summarized in Table 26 below.

Table 26: Measures for Economic and Financial Barriers: Climate Proofing Assets

CRITICAL BARRIER	ROOT CAUSES	ENABLING MEASURES
High costs of the phased implementation of [risk management] *P*lan	▪ Inadequate budget allocation for proactive management of Water Utility's infrastructure ▪ Limited available national finances ▪ Inadequate revenue generated by the Water Utility *and annual [government] budget allocations are insufficient* ▪ National finance team/decision-makers do not fully grasp the implications of delaying comprehensive risk management *[funds are allocated to the various other projects competing for limited national finances]* ▪ Limited success in preparing successful technical proposals to obtain funding from international donors and lending agencies ▪ Limited ability of the government to co-finance infrastructure projects	▪ Prioritize proactive management by providing adequate technical and financial resources to Utility ▪ Promote greater financial independence of Utility by supporting greater revenue generation [through tariff reform, reducing NRW[10] etc.] and increasing the budget allocation [to offset consumption by the public sector] ▪ Promote increased awareness about climate-proofing to protect investment/assets and limit longer-term expenditure by Utility ▪ Provide necessary support for Utility's staff in preparing technically sound and competitive proposals for international financing bodies ▪ Encourage government to allocate funding for necessary upgrades to water infrastructure [considered national development initiatives], thus strengthening the applications for climate financing

2.5.2.2. Non-financial Barriers and Measures

A list of eleven (11) non-financial barriers to climate-proofing was presented, of which one (1) was considered critical to adoption and decomposed by the TWGs *(*Table 20 *)*. Five of the remaining ten (10) were ranked *low* since stakeholders were sure that measures and/or resources were already in place to overcome them, the other five were ranked *medium* and the following measures were suggested for mitigating them:

[10] NRW: Non-revenue Water – water that is produced but *lost* alone the distribution line before it reaches the customer (such as through pipeline leaks or inaccurate metering).

Table 27: Summary of Stakeholder Discussion on Non-Financial Barriers and Measures: Climate Proofing Assets

NON-FINANCIAL BARRIERS	POSSIBLE MEASURES
Political will to prioritize proactive management of Utility	Galvanize political support by engaging decision-makers
Revenue loss by Utility during service interruptions	Reduce revenue loss by scheduling shorter system downtime and resolve to only begin disruptive work when all the equipment and human resources are in place
Lack of coordination across ministries and government departments leading to hiccups, delays and longer project timeline	Encourage public sector reform that will allow streamlining of bureaucratic procedures that limits 'red tape' and encourage greater cross-agency collaboration
Lack of transparency – financial and non-financial	Promote a more transparent process by routinely and periodically updating the public about progress, a portion of budget spent and next steps etc., to engender public confidence throughout the project cycle
Inadequate information and/or misinformation about the process	Develop a communication strategy and various information tools to both educate and inform the public about the ongoing works

Annex E shows the Problem Tree of *causes* and *effects* for – *increased levels of public concerns about the lengthy project timeline*. It outlines how poor public perception about the Utility's ability to remain on schedule and the lack of support by the demographic most dependent on piped water, would result in higher levels of public outcry about lengthy periods of network downtime. The Objective Tree highlights enabling *measures* defined to proactively limit concerns and promote public buy-in.

Table 28 provides a summary of the measures.

Table 28: Measures for Non-financial Barriers: Climate-proofing Assets

CRITICAL BARRIER	ROOT CAUSES	ENABLING MEASURES
Increased levels of public concerns about the lengthy project timeline	▪ High levels of negative sentiments about proposed infrastructure work ▪ Poor public perception about the government's and Utility's ability to maintain the proposed project schedule ▪ Widespread fears about lengthy water network outages ▪ Increased consumer anxiety about the availability of piped water ▪ Lack of support from vulnerable demographic	▪ Develop a comprehensive communication plan with a range of communication tools to keep the public updated about progress, delays and service interruptions [using diverse communication channels] ▪ Outline [and update] a pragmatic project schedule and communicate changes in a timely manner ▪ Schedule and publicize shorter periods of network outages, and focus on limited rationing to mitigate against anxiety about network outages

CRITICAL BARRIER	ROOT CAUSES	ENABLING MEASURES
	groups that predominantly depend on Utility supply	▪ Map out Utility dependent zones/communities and ensure scheduled outages have limited impacts on the most vulnerable

2.6. BARRIER ANALYSIS AND POSSIBLE ENABLING MEASURES FOR STORMWATER RECLAMATION AND REUSE

2.6.1. General Description of Stormwater Reclamation and Reuse

Stormwater reclamation involves the collection, accumulation, treatment, and storage of precipitation for reuse. Unlike rainwater harvesting, runoff is collected from *storm* drains, waterways and roadways instead of rooftops. Micro-catchments can be used to divert or slow runoff so that it can be stored before entering receiving waters. After extreme rainfall and seasonal weather events, local watersheds are inundated with flash flood waters that quickly drain into the marine environment. Harvesting this water for non-potable uses, like groundwater recharge, agricultural irrigation or replenishing natural wetlands, could provide social, environmental and economic benefits – combating flooding and soil erosion and lessening nutrient loads discharged to marine waters (Pavelic et al. 2010).

In Antigua diffusion of this technology will be focused on the Christian Valley Watershed - #3 *(see* Figure 2Figure 2: Antigua's Six Major Watershed Highlighting Streams and Waterways*)*, on the southwest coast of the island. Christian Valley is the third largest by area, and most productive in terms of the annual yield of groundwater in cubic feet per year (Cooper & Bowen 2001; GENIVAR 2011; HRW 2019). Stormwater reclamation and reuse would achieve a few key results in the Christian Valley watershed: i.) accumulation of surface water stores to accommodate groundwater recharge, ii.) provision of additional volumes for crop irrigation and watering livestock in the local area; and iii.) contribution to better overall watershed management through flood mitigation and soil erosion control – this would be particularly beneficial to vulnerable communities in the lower watershed.

Groundwater recharge will potentially increase productivity with the co-benefit of lessening the island's dependency on seawater desalination for potable water supply. As secondary benefits water retained in these check dams/micro-catchments can be used by farmers and will also lessen flash flooding downstream in the Jennings and West Palm Beach areas. APUA would maintain responsibility for facilities and infrastructure and facilitate groundwater recharge; while the Ministry of Agriculture's Extension Division will liaise with farmers in the area and the National Office of Disaster Services will work closely in the interest of residents inhabiting downstream flood-prone areas. The technology aligns well with the National Strategy and Action Plan (NASAP), the

Integrated Water Resources Management (IWRM) Policy and Environmental Protection and Management Act 2019.

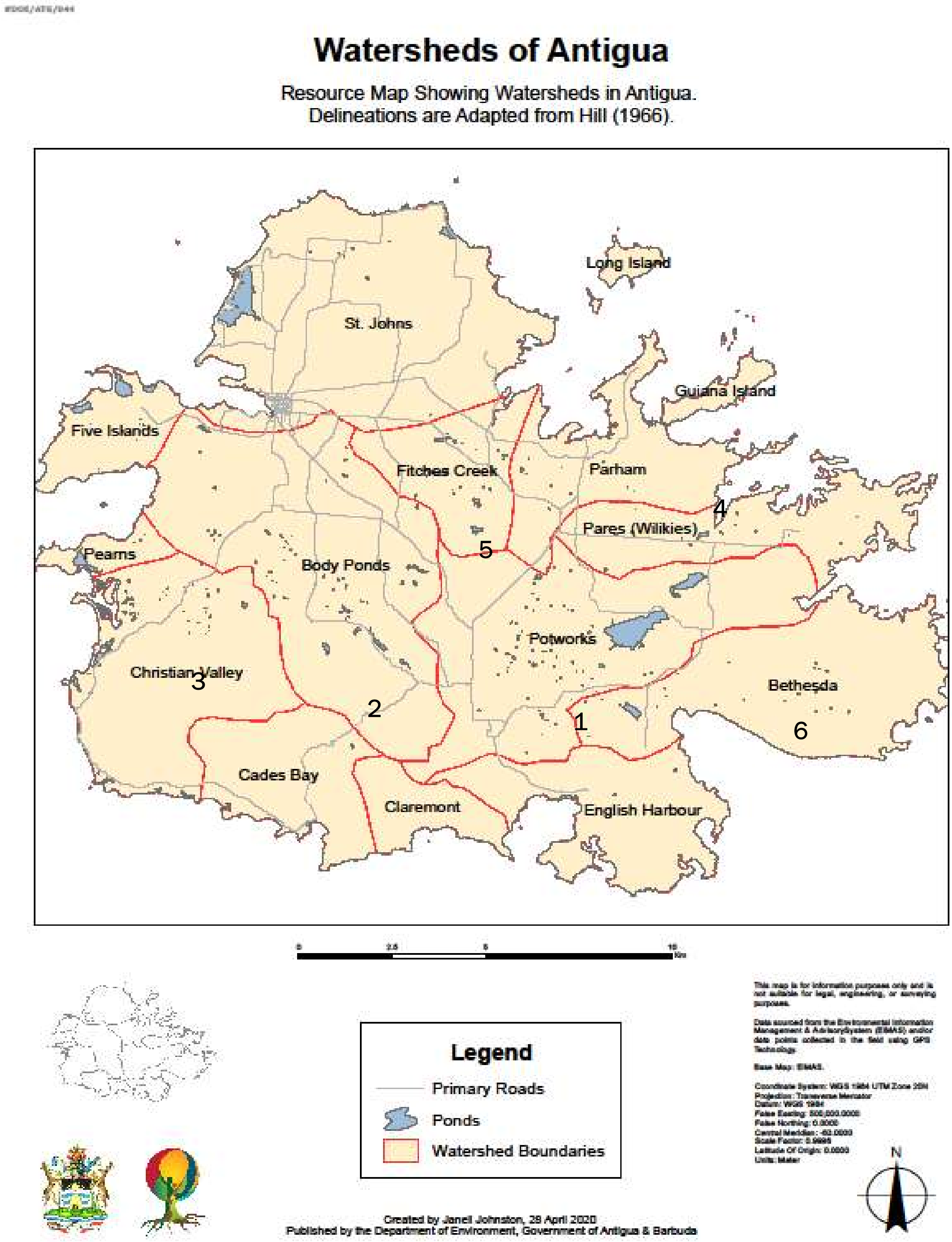

Figure 2: Antigua’s Six Major Watershed Highlighting Streams and Waterways
Source: Date Management Unit - DoE

2.6.2. Identification of Barriers for Stormwater Reclamation and Reuse

Stormwater reclamation and reuse are categorized as a Non-Market | Publicly Provided Good, which addresses holistic watershed management that results in quantifiable social, economic and environmental co-benefits to the local area and wider Antiguan public. The surface water catchments will be provided through large investments approved at the government level and executed by public sector agencies or through public-private partnerships.

APUA has outlined a strategy to increase groundwater abstraction by 0.3mgd[11]and has identified managed aquifer recharge to augment groundwater stores. Given the high cost of large-scale infrastructure installation and the watershed protection guidelines in the EMPA (2019), the Utility is partial to the use of *green infrastructure* such as ponds and check dams to promote seepage in the Christian Valley area. The cost estimated by HR Wallingford to achieve the goal of an additional 0.3mgd is USD 5M over three years (HRW 2019).

The initial list of barriers presented to the TWG was reviewed and the resulting prioritization is detailed in Table 29. One (1) economic and financial barrier was ranked as critical. This was:

i.) High costs of civil works – equipment, operation, and maintenance – for construction of check dams / micro-catchments.

Table 29: Prioritization of Barriers for Stormwater Reclamation and Reuse

CATEGORIZATION OF BARRIERS – STORMWATER RECLAMATION AND REUSE					
CATEGORY	BARRIER	LEVEL OF IMPORTANCE			
		HIGH	MED	LOW	RANK
ECONOMIC & FINANCIAL	Cost of designing new and/or improving existing stormwater management plan/s for the southwest			X	
	High costs of civil works [equipment, operation and maintenance] for construction of check dams / micro-catchments	X			1
	Availability of donor funding and/or loan facilities for necessary finances		X		
NON-FINANCIAL	Low priority in APUA's Master Plan			X	
	Lack of technical capacity for all phases [within Utility and available in-country]		X		
	Lack of coordination [and shared interest] across relevant ministries and government agencies	X			2
	Little to no public buy-in			X	
	Few established community NGOs to spearhead wetlands restoration activities			X	
	Limited understanding [by the public] of the process and/or need for the investment		X		

[11] mgd = million gallons per day

CATEGORIZATION OF BARRIERS – STORMWATER RECLAMATION AND REUSE					
CATEGORY	BARRIER	LEVEL OF IMPORTANCE			
		HIGH	MED	LOW	RANK
	Concerns about disruptions in livelihoods within the agriculture sector			X	
	Process of acquiring private lands for micro-catchments and/or surface reservoirs			X	

2.6.2.1. Economic and Financial Barriers and Measures

The economic and financial barriers identified included design and implementation costs for all the activities involved in constructing surface water catchments – check dams and micro-catchments – to collect and store stormwater for secondary uses. A total of three (3) barriers were listed in this category, of which one (1) was considered a critical / killer barrier. There were, however, robust stakeholder discussions around all three barriers; and the following general measures were suggested for future exploration:

- The cost for designing a new stormwater management plan for the south-west was deemed negligible, since all the necessary baseline information, data and disaster management plans can be aggregated from government agencies such as the National Office of Disaster Services (NODS), Department of the Environment, Ministry of Works, Ministry of Agriculture and Lands and APUA. Further, a team of qualified inter-agency personnel can be assembled to design the surface water catchments, and should it become necessary, other local private sector technicians can be brought on board to assist.
- Accessing donor funds was acknowledged to be challenging, however as with successful *de-risking*, strengthening institutional capacity to prepare competitive concept notes and proposals will help overcome this hurdle. Given that the APUA – as legislated in Public Utilities Act (GoAB 1973)– will ultimately be responsible for overseeing a stormwater management scheme, and owing to their desire to access funding for other climate-smart technologies, capacity building within the Utility will be greatly beneficial.

A detailed Problem Tree is shown in Annex F highlighting the *causes* and *effects* for the critical economic and financial barrier – *high costs of civil works for construction of check dams and micro-catchments.* It outlines how high construction and labour costs, along with the limited availability of relevant materials would result in negative impacts on vulnerable households, watershed health and overall national water security. While the Objective Tree highlights *measures* to overcome these root causes, and the resulting *benefits* for the Water Utility and improved social, economic and environmental health in the watershed.

The full range of measures is summarized in Table 30 below.

Table 30: Measures for Financial Barriers: Stormwater Reclamation and Reuse

CRITICAL BARRIER	ROOT CAUSES	ENABLING MEASURES
High costs of civil works for construction of check dams and micro-catchments	▪ High costs for equipment and labour ▪ Limited number of local machine/equipment operators with relevant skills ▪ Highly specialized jobs will be outsourced to regional/international operators ▪ Lack of adequate volumes of materials [on the island] results in increased costs for all construction projects ▪ High importation costs for materials	▪ Promote expansion opportunities for local heavy equipment/earthworks companies by providing them with construction contracts; thus, eliminating public sector purchase of equipment or employment of skilled workers ▪ Partner with tertiary institutions and equipment suppliers to provide training and certification for local heavy equipment operators to avoid outsourcing specialized jobs ▪ Increase production at local quarries to offset the demand for increased volumes of materials during project implementation** ▪ Reduce material costs and delays by procuring imported materials in bulk

** The Department of Environment would have to be vigilant in its role as *environment overseer* to ensure that this is done in a sustainable way; halting production at both publicly and privately operated quarries when they reach their projected maturity.

2.6.2.2. Non-Financial Barriers and Measures

A list of eight (8) non-financial barriers to stormwater reclamation and reuse was presented, of which one (1) – lack of coordination [and shared interest] across relevant ministries and government agencies, was considered critical to adoption. However, during the stakeholder briefing meeting and subsequent presentation to the TAC it was concluded that since it speaks to overall public sector organization and reform; while it was identified as a barrier to this technology, it is a potential barrier to the implementation of all large-scale State-level projects. Hence, overcoming this barrier will not only strengthen the diffusion of stormwater reclamation and reuse but also benefit other areas of national development. Table 31 summarises all the stakeholder discussions on the non-financial barriers and possible measures.

Table 31: Summary of Stakeholder Discussion on Non-Financial Barriers and Measures: Stormwater Reclamation and Reuse

NON-FINANCIAL BARRIERS	POSSIBLE MEASURES
Lack of technical capacity for all phases – within Utility and available in-country	Assemble the necessary team of experts from *any* relevant public sector agency and employ a collaborative effort to execute adoption, and Include private sector experts at various phases of diffusion where their input can be maximized

NON-FINANCIAL BARRIERS	POSSIBLE MEASURES
Lack of technical capacity for all phases – within Utility and available in-country	Upskill APUA's engineers and provide cross-training opportunities with other technical experts
Few established community NGOs to spearhead wetlands restoration activities	Promote the technology's overarching benefit for holistic watershed management, and where appropriate encourage wetlands restoration activities, and Utilize schools, churches and ad hoc community groups for wetlands restoration
Limited understanding [by the public] of the process and/or need for the investment	Develop context-specific, local area and national education and awareness drives to inform the public about the technology and its benefits - Target farmers with the narrative of increased irrigation supplies; - Engage Agriculture to allot more leases of agriculture lands in the areas closer to the new surface water catchments; - Target downstream communities with information about flood mitigation benefits Promote the benefits of groundwater recharge for Utility production and decreasing Antigua and Barbuda's carbon footprint
Lack of coordination [and shared interest] across relevant ministries and government agencies	Strengthen public sector capacity for project coordinating and management within the PSIP (the central government that spearheads the implementation of capital budget projects) Streamline project implementation processes by eliminating the number of agencies needed to provide approval Promote effective and clearly defined inter-agency communication channels

2.7. BARRIER ANALYSIS AND POSSIBLE ENABLING MEASURES FOR ATMOSPHERIC WATER GENERATORS

2.7.1. General Description of Stormwater Reclamation and Reuse

Atmospheric Water Generators (watermakers) produce potable water by extracting vapour from humid, ambient air – either by condensation or exposing the air to hygroscopic substances (drying agents) called desiccants. In modern water makers, vapour from the air is drawn into the external/roof-mounted unit and adsorbed into a specialized desiccant. Water is then desorbed and condensed into droplets. The liquid is piped into a tank where it can receive up to three levels of treatment before the purified drinking water is dispensed at a tap or cooler *(see* Figure 3*)*. Some water makers are solar-powered and can even be fitted with network-connected water quality monitoring systems (Watergen 2018; ZeroMassWater 2018).[12,13]

[12] SOURCE Perfect water for every person, every place. Zero Mass Water, www.zeromasswater.com

[13] Genius Technology Energy efficient heat transfer and dehumidifying technologies. Watergen USA, https://www.watergenusa.com/technology-2/technology/

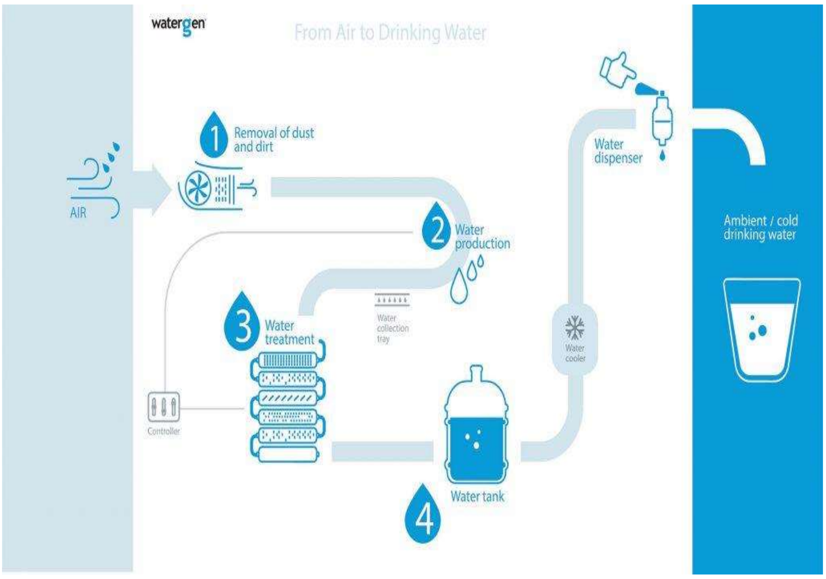

Figure 3: AWG - Process Diagram
Source: Watergen (2018)

Individual AWG units can be ground, roof or trailer mounted, allowing for a range of applications. The TNA will focus on piloting *roof* units on private or public buildings that provide drinking water dispensed at a cooler throughout the day, with a specific focus on offices, schools, and health facilities. The estimated retail price for an office unit that generates approximately 7gpd and has a storage capacity of 15 gallons is USD 2,185 or XCD 9,795.15.

2.7.2. Identification of Barriers for Atmospheric Water Generators

Atmospheric Water Generators are categorized as Consumer Goods, targeting commercial and institutional end-users. The initial list of barriers discussed with stakeholders that resulted in the prioritization is detailed in Table 32. One (1) economic and financial and one (1) non-financial were ranked as critical / killer barriers. These were:

i.) Higher initial investment in comparison to traditional water coolers

ii.) Customer concerns about performance and reliability.

Table 32: Prioritization of Barriers for Atmospheric Water Generators

CATEGORIZATION OF BARRIERS – SOLAR PUMPING SYSTEMS					
CATEGORY	BARRIER	LEVEL OF IMPORTANCE			
		HIGH	MED	LOW	RANK
ECONOMIC & FINANCIAL	Consumers apprehensive to make the higher initial investment in comparison to traditional water coolers	X			1
	Perceived threat to the business model of bottled water companies		X		
	Higher longer costs from supplementing supplies with bottled water purchases		X		

CATEGORIZATION OF BARRIERS – SOLAR PUMPING SYSTEMS					
CATEGORY	BARRIER	LEVEL OF IMPORTANCE			
		HIGH	MED	LOW	RANK
NON-FINANCIAL	Consumer concerns about systems performance and reliability	X			2
	Limited understanding of the technology and potential benefits		X		
	Lack of local capacity for installation and maintenance		X		
	No known local or regional retailers		X		

2.7.2.1. Economic and Financial Barriers and Measures

The barriers in the category considered the financial investment of the consumer, both initially and in the longer term and the potential economic impact on businesses that promote existing technologies which may be displaced by the introduction of AWGs. Of the three barriers, two were ranked as medium and the other critical – which was decomposed in the logical framework.

Table 33 shows a price comparison of owning and maintaining an AWG versus traditional water coolers that utilized 5-gallon refills. The analysis is done for a medium-sized office with 20 staff. Based on the analysis the AWG will pay for itself over 24 months, after which it would account for USD 1,680 or XCD 4,500 savings to the business by eliminating the purchase of 5-gallon refills.

Table 33: AWGs versus Conventional Water Coolers

DEVICE	WATER COOLER (TOP LOAD)	AWG	COMMENTS
Retail Cost	USD 1,190 or XCD 3,200	USD 2,185 or XCD 9,795.15	2 units @ USD 595 or XCD 1,600 per unit
5-gallon refills / month	USD 140 or XCD 375	N/A	25 5-gallon refills @ USD 5.5 or XCD 15 per refill
Maintenance	USD 8 - 10	USD 8 –10	Sanitizing

Annex G shows the Problem Tree of *causes* and *effects* for – *consumers apprehensive to make the higher initial investment in comparison to traditional water coolers.* It outlines how market saturation of traditional water coolers, wide distribution of 5-gallon refills and consumer inexperience with new technology would result in a missed opportunity to diversify the market with this sustainable technology option. The Objective Tree highlights *measures* that could be used to overcome the underlying causes, create new business opportunities and introduce the self-sustaining water cooler into the public and private sector.

Table 34 provides a summary of the measures discussed.

Table 34: Measures for Financial Barriers: Atmospheric Water Generators

CRITICAL BARRIER	ROOT CAUSES	ENABLING MEASURES
Consumers apprehensive to make the higher initial investment in comparison to traditional water coolers	▪ Side-by-side comparisons [AWGs vs. conventional water coolers] result in AWGs being considered unexceptionally costly ▪ Technology is completely new to the local and regional market ▪ Traditional water coolers are good sellers and 5-gallon refills are widely available and competitively priced ▪ Local suppliers hesitate to stock the more expensive water coolers	▪ Establish partnerships between local retailers and AWG manufacturers [e.g., leveraging multilateral relationships established through the Chamber of Commerce] ▪ Incentivize local retailers to purchase and stock AWG units by zero-rating import duties and taxes ▪ Design a robust education and awareness campaign to educate consumers about the technology and help them understand the long-term benefits ▪ Encourage bottled water business to enter the market and provide rental or rent-to-own options to consumers [e.g., through avenues like the entrepreneurial development programme]

2.7.2.2. Non-Financial Barriers and Measures

Four (4) non-financial barriers were considered, and they were ranked between medium and high in their levels of importance. Given that the technology is completely new to the Antiguan and Barbudan market, all barriers were equally considered, and there seemed to be a common thread of *uncertainty* across them all. The Problem and Objective Trees in Annex G explain the logical process that was undertaken to determine the root causes of the most critical non-financial barrier – *high consumer concerns about system's performance and reliability* and identifies practical measures that can be employed to overcome them. Table 35 provides a summary of the measures:

Table 35: Measures for Non-Financial Barriers: Atmospheric Water Generators

CRITICAL BARRIER	ROOT CAUSES	ENABLING MEASURES
High consumer concerns about system's performance and reliability	▪ Inadequate knowledge about the inner workings of the technology leading to widescale distrust ▪ Uncertainty about performance in different weather conditions ▪ Lack of trained technician on the island who are qualified to install and maintain units	▪ Design a robust education and awareness campaign to educate consumers about the technology and help them understand the overall process ▪ Provide training and certification for technicians ▪ Pilot technology [e.g., in government buildings] and disseminate results to engender consumer confidence

CRITICAL BARRIER	ROOT CAUSES	ENABLING MEASURES
	▪ Increased concerns about the durability of externally [roof] mounted units	

2.8. LINKAGES OF WATER SECTOR BARRIERS ACROSS TECHNOLOGIES

A summary of the linkages of critical barriers for each water sector technology is presented in Table 36. During consultations, stakeholders identified common challenges for transfer and diffusion that were expected across the prioritized technologies. While, in some instances, the linkages were not represented in the critical / killer barrier, all linkages that were discussed with stakeholders, and addressed in this report are represented in the summary. [X] indicates the linkages for killer barriers, while [*] shows the linkage with a lower-ranked – but nevertheless significant – barrier.

Table 36: Linkages of Barriers by Technology in the Water Sector

BARRIERS	WATER SECTOR CLIMATE-SMART TECHNOLOGIES					
	SOLAR PUMPING	RAINWATER HARVESTING	WATER SAVERS	CLIMATE-PROOFING	STORMWATER	AWGS
High initial capital investment for system components, design and installation services [Capital Costs]	X	*				
Limited established retailers and systems on the island [Market Availability]	X	X	*			X
Cost and availability of unconventional rainwater storage options [Market Availability]	*	X				
High costs to refurbish community reservoirs or install community tanks and catchments [Capital Costs]	X	X		*		
No incentives that encourage pairing climate-smart technologies [Incentives & Pairing]	X	X	*			
Low awareness about the water saving benefits of WSDs [Education and Awareness]	X	X	X	X	X	X
High costs of the phased implementation of [risk management] *Plan* [Implementation Costs]				X	X	
Increased levels of public concerns about the lengthy project timeline				X	*	

BARRIERS	WATER SECTOR CLIMATE-SMART TECHNOLOGIES					
	SOLAR PUMPING	RAINWATER HARVESTING	WATER SAVERS	CLIMATE-PROOFING	STORMWATER	AWGS
[Implementation Timelines]						
High costs of civil works for construction of check dams and micro-catchments [Capital and Implementation Costs]				*	X	
Consumer apprehensive to make the higher initial investment in comparison to traditional water coolers [Capital Costs]	X					X
High consumer concerns about system's performance and reliability [Performance and Maintenance]	*		*			X

Cost – capital, implementation and operation – was evidently a barrier that permeated all six water sector technologies. This related to the cost to the consumer of procuring market goods and that of the government or subsidiary agency acquiring, implementing and sustainably operating publicly provided goods. The need for increased *education and awareness* also pervaded the entire group of technologies, this ranged from educating the public about new products and their usefulness in the local context of building resilience, to bringing about awareness of the need for undertaking larger scale, disruptive projects to improve national water security in the longer term.

The common barriers across the three technologies classified as consumer goods were related to *market availability* and *incentives for pairing technologies.* Transfer and wide-scale diffusion of these technologies will only be achieved when new products are market tested and made available by local retailers. Further, full-scale diffusion will be encouraged if supporting incentive programmes that promote the uptake of complementary technologies are instituted. This again highlights the need for targeted *education* and *awareness* campaigns in breaking established cultural norms and encouraging behavioural change in the general population.

Finally, when addressing the two publicly provided goods, *institutional/organizational reform* within public sector agencies, to promote a more streamlined implementation process for large-scale, big-budget projects, was seen as a necessity to achieve successful technology transfer. While the involvement of multiple government agencies and several levels of approval may not be avoided, project implementation will benefit from a more structured process that eliminates unnecessary bureaucratic red tape.

2.9. ENABLING FRAMEWORK FOR OVERCOMING BARRIERS

This section details a complete framework of enabling measures for overcoming all identified critical barriers. Along with the *measures* outlined in the previous sections; *benefits, expected timeframe, projected costs* and *agencies or entities* critical to transfer and diffusion are compiled below in Table 37. Although stakeholders identified major partners – from the public and private sectors – who would be involved in technology transfer, the table does not reflect an exhaustive list. Similarly, projected costs are estimated from existing research and reports are done before the TNA project – further details will be outlined in the Technology Action Plan.

Table 37: Enabling Framework for Water Sector Technologies

BARRIER	MEASURES	BENEFITS	TIMEFRAME & COSTS	AGENCY | ENTITY
High initial capital investment for system components, design and installation services.	▪ Encourage solar energy specialists [and water equipment service providers] to expand commercial interests to include *solar* water solutions ▪ Provide access to public sector solar specialists – *Pro Bono* or at minimum market rate – to advise interested residents on sizing and design ▪ Incentivize local suppliers to invest in solar pumping business opportunities, such as partnering with overseas manufacturers/suppliers and assembling equipment locally ▪ Facilitate upskilling opportunities for local plumbing and electrical technicians to increase local capacity and availability of technical skills	▪ High potential for full-scale market penetration of solar pumps and accessories ▪ Multiple options of solar pumps and replacement parts readily available in-department/hardware stores ▪ Solar pumps and accessories are feasible at the residential and commercial levels ▪ Increased economic opportunities for local businesses ▪ Increased number of new employment opportunities for local technicians [solar, electrical]	Short | Medium Term Equipment Cost: <u>Residential</u>: USD 335 – USD 1,450 (pump only) <u>Commercial</u>: USD 950 – USD 1,500 (pump only) <u>Community</u>: USD 3,522 (pump only) <u>Controllers</u>: USD 253 – USD638 --- Overall Cost: ~USD 1.5M (project) ~USD 550K (private sector)	- Dept. of Environment; - Min. of Energy; - Community NGOs; - Chamber of Commerce; - Local retailers [department and hardware stores]; - Association of Plumbing and Electrical Technicians
Limited established retailers and package systems on the island	▪ Encourage local retailers to purchase, stock and market small scale, package solar pumping systems for residential and commercial applications ▪ Facilitate quick repairs and limited system downtime by having adequate stock of essential replacement parts available on the island [by partnering with regional suppliers/manufacturers]			
Cost and availability of unconventional	▪ Provide incentives for retailers to import, stock and market a range of storage options	▪ Potential opportunities to develop new unique, rainwater storage products	Short | Medium Term	- Min. of Social Transformation – Community Dev. Division; - Min. of Agriculture;

BARRIER	MEASURES	BENEFITS	TIMEFRAME & COSTS	AGENCY | ENTITY
rainwater storage options	▪ Promote a wide range [max. 5] of storage options and encourage consumers to examine and compare costs and applicability [versus concrete in-ground cisterns] ▪ Stimulate local interest in designing and demonstrating *novel* low-cost storage by increasing access to financing and lowering investment risks	constructed from locally available raw materials ▪ New business opportunities for local retailers to import and market a range of alternative storage options ▪ Increased opportunities for renters / vulnerable demographic groups to harvest rainwater during periods of heavy rainfall ▪ Renters / vulnerable demographic groups have adequate storage for water during periods of drought ▪ Increased water security for the most vulnerable across the State	Undetermined costs	- Development Control Authority (DCA); - Chamber of Commerce; - Local retailers [department and hardware stores]; - Micro-financing organizations
High costs to refurbish community reservoirs or install community tanks and catchments	▪ Target donations [from the business community, overseas residents, local government etc.] to accumulate seed funds to jumpstart refurbishment projects ▪ Organize community workdays to elicit volunteer labour from community residents [and the willing public] to assist with renovations ▪ Hire skilled labour where necessary ▪ Strengthen technical capacity within community groups ▪ Strengthen proposal writing capacity by seeking training opportunities for community NGO members ▪ Improve collaboration between community NGOs and schools, and utilize the school	▪ Community reservoir refurbishment completed in ten (10) target communities ▪ Increased potential for rainwater capture during periods of heavy rainfall ▪ Increased volumes of emergency community water supply for periods of drought or following an extreme weather event ▪ Increased water security at the community level ▪ Income generated from community industries such as green spaces, gardens and small-scale industries; revenue used to operate and maintain reservoirs	Medium Term Costs: USD 2.5M (minimum)	- Min. of Social Transformation – Community Dev. Division - Community NGOs; - Grant facilities (GEF Small Grants / DoE); - Micro-financing organizations; - Local government / Constituency Office

BARRIER	MEASURES	BENEFITS	TIMEFRAME & COSTS	AGENCY | ENTITY
	as a channel for executing small scale project activities ▪ Create opportunities for income generation in the early phases of the refurbishment project to promote various sources of income [thus limiting reliance on free money]			
No incentives that encourage pairing RWH with *solar pumping systems*	▪ Promote *solar pumping systems* as a complementary technology to rainwater harvesting for residential and community storage systems ▪ Increase awareness about potential uses of *solar pumping* along the rainwater harvesting chain – specifically treatment and distribution ▪ Create a program/s that provide financial incentives to individuals and groups interested in acquiring *solar pumping equipment*	▪ New opportunities created for solar-powered water treatment and distribution ▪ Decreased likelihood that harvested rainwater remains unused; become stagnant and the breeding grounds for insects ▪ Decreased potential for public health concerns ▪ Incentives allow solar *add-ons* to become available to a wider cross-section of the population	Short | Medium Term Undetermined costs	- Ministry of Finance; - Min. of Social Transformation – Community Dev. Division - Dept. of Environment
Limited education and awareness about the water-saving benefits of household appliances and devices	▪ Increase awareness about water consumption and conservation practices around the entire property and encourage consumers to become practical/responsible water users ▪ Disseminate information about the general in-home water use patterns and encourage homeowners to analyse personal trends ▪ Encourage practice change starting in areas or with appliances that use and/or waste the most water	▪ Greater potential for nationwide behaviour [practice] change relating to water consumption and conservation ▪ Increased opportunities to promote water conservation and a cultural shift towards zero wastage ▪ Property owners observe a decrease in metered volumes of water [reflected on utility bills] and harvested water lasts for longer periods	Short | Medium Term Costs: USD 150K (minimum)	- Min. with responsibility for the Environment; - Min. of Education; - Civil Sector Organizations (CSOs); - NGOs; - Bureau of Standards

BARRIER	MEASURES	BENEFITS	TIMEFRAME & COSTS	AGENCY | ENTITY
	▪ Promote the implementation of water efficiency standards for devices/appliances ▪ Educate homeowners about the benefits, both personal and nationwide, of making informed choices based on efficiency	▪ The utility can utilize production volumes to service underserved areas or extend network coverage		
High costs of the phased implementation of [risk management] *Plan*	▪ Prioritize proactive management by providing adequate technical and financial resources to Utility ▪ Promote greater financial independence of Utility by supporting greater revenue generation [through tariff reform, reducing NRW[14] etc.] and increasing the budget allocation [to offset consumption by the public sector] ▪ Promote increased awareness about climate-proofing as a means to protect investment/assets and limit longer-term expenditure by Utility ▪ Provide necessary support for Utility's staff in preparing technically sound and competitive proposals for international financing bodies ▪ Encourage government to allocate funding for necessary upgrades to water infrastructure [considered national development initiatives], thus strengthening the applications for climate financing	▪ Increased resilience of Reverse Osmosis (RO) infrastructure, such as buildings, intake/outfall, pumps etc. ▪ Decreased damage during extreme weather events ▪ Shorter downtime periods before Utility network service is restored ▪ Improved national water security	Medium | Long Term Costs: USD 5M (minimum)	- APUA – Water Division; - Government of Antigua and Barbuda; - International lenders / Loan facilities - Ministry of Works; - Min. with responsibility for the Environment; - Min. of Agriculture and Lands
Increased levels of public	▪ Reduce negative sentiments by devising a comprehensive communication plan to	▪ Full commitment and support from politicians and decision-makers in	Medium | Long Term	

[14] NRW: Non-revenue Water – water that is produced but *lost* alone the distribution line before it reaches the customer (such as through pipeline leaks or inaccurate metering).

BARRIER	MEASURES	BENEFITS	TIMEFRAME & COSTS	AGENCY | ENTITY
concerns about the lengthy project timeline	keep the public updated about progress, delays and service interruptions [using diverse communication channels] ▪ Increase public confidence in the Utility by outlining a realistic project schedule and consistently communicating changes promptly ▪ Mitigate widespread fears and anxiety by scheduling and publicizing shorter periods of network outages, and focus on limited rationing ▪ Map out Utility dependent zones/communities and ensure scheduled outages have limited impacts on the most vulnerable	prioritizing larger scale | high impact projects ▪ Decreased spending on reactive maintenance or emergency management interventions ▪ Decrease in service disruptions following major climate events ▪ Reduced public outcry due to shortened periods of water network downtime	Costs: USD 65K	
High costs of civil works for construction of check dams and micro-catchments	▪ Promote expansion opportunities for local heavy equipment/earthworks companies by providing them with construction contracts; thus, eliminating public sector purchase of equipment or employment of skilled workers ▪ Promote training opportunities for local heavy equipment operators to avoid outsourcing specialized jobs ▪ Increase production at local quarries to offset the demand for increased volumes of materials during the project period ▪ Reduce material costs by purchasing imported materials in container/vessel loads	▪ High rates of groundwater recharge achieved ▪ Increased groundwater extraction potential of Water Utility ▪ Lower volumes of runoff continue downstream, thus mitigating flooding in the lower watershed ▪ Net positive impact on overall watershed health ▪ Increased volumes of water available for crop irrigation and livestock watering ▪ Increased opportunities to promote agriculture in the watershed, improving local food security	Medium | Long Term Cost: USD 3.5M (estimated)	- APUA – Water Division; - Government of Antigua and Barbuda; - International lenders / Loan facilities - Ministry of Works; - Min. with responsibility for the Environment; - Min. of Agriculture and Lands

3. BUILDING SECTOR TECHNOLOGIES

3.1. PRELIMINARY TARGETS FOR TECHNOLOGY TRANSFER AND DIFFUSION

As a broad overview, the targets for the two (2) prioritized building sector technologies are as follows in Table 38 and Table 39.

Table 38: Preliminary Targets for Best Roof Pitch Angle Design

Technology	Roof Pitch Angle
Primary target	Public awareness campaign. 20% of new private buildings incorporate technology by 2030.
Required Investment	USD 103,260
Expected lifetime	Life of the building
Climate change impacts	Improved resilience to higher categories of hurricanes

Table 39: Preliminary Targets for LED Lighting Design

Technology	LED Lighting for Households
Primary target	30,000 installed in homes replacing 20,000 incandescent light bulbs and 10,000 CFL over 2 years
Required investment	A minimum of USD 245,000 for purchasing and distributing the bulbs. Public awareness campaign USD 45,000 Total = USD 245,000
Expected lifetime	4 years
Expected economic benefits	Annual energy saving in of USD29,800 for every 1,000 incandescent 60W replaced with LED light, which results in reducing energy consumption by 3,037MWh/year Reduce oil importation for electricity production
Climate change impacts	It is expected to reduce annual emissions of 8039.28-ton CO2 eq

3.2. BARRIER ANALYSIS AND POSSIBLE ENABLING MEASURES FOR ROOF PITCH ANGLE

3.2.1. General Description of Roof Pitch Angle

Hurricanes are the most significant annual natural risk to infrastructure for the Caribbean region. In recent years there has been an increase in the formation of category five hurricanes that pose a great threat to the Caribbean islands. The heavy rains and high winds are usually too powerful for the average roof to withstand, resulting in devastating roof damage or loss.

Traditionally, construction methodology focused on steep roof pitches which are more resistant to high wind gusts, as depicted in Figure 4. This design trend was prevalent in the post-emancipation period for small and medium-sized dwellings in Antigua and Barbuda[15]. Over the past 70 years, however, steeply pitched roofs have become less prominent in local building design.

The pitch angle of the roof is indirectly proportional to the resistance against wind forces. Simply put, the steeper the pitch, the less the atmospheric pressure change forces on it when it is associated with an aperture for venting *(see Figure 4)*. An increased pitch roof of 8/12 to 9/12 is steep enough to resist uplift but shallow enough to resist overturning. Flat and low-slope roofs typically fail in high winds due to a force known as “uplift”.

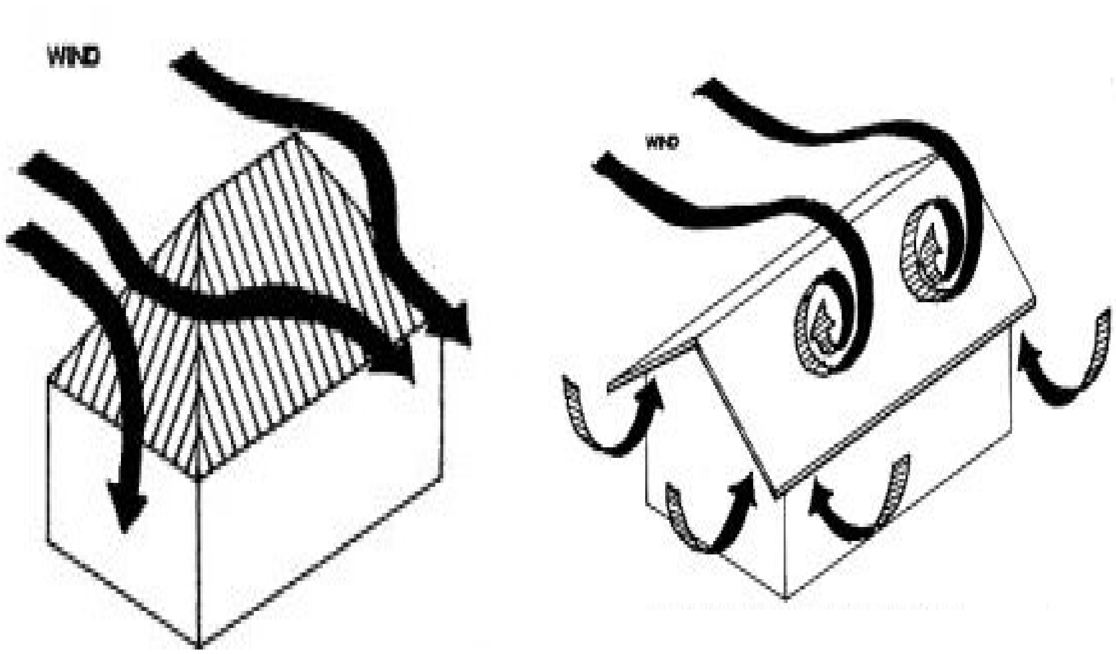

Figure 4: Airflow around steep pitch hip roof (left) vs regular pitch gable roof (right) [16]

The use of steep pitch roofs has been recommended by existing regional literature on hurricane-resistant design[17]. Increased pitch roofs resist uplift, with 30^{o} or 7/12 pitches being best performers in storms[18].

In addition to the pitch angle, the shape of the roof can assist in reducing uplift forces. As shown in Figure 4, the four-sided hip roof fares better than the gable roof design against strong winds. The design of the hip roof allows easier air flow.

[15] Crain, E. (1994). Historic Architecture in the Caribbean Islands. University Press of Florida.
[16] Sourced from: http://dwacaribbean.com/design-guidelines-for-hurricane-resistant-buildings/
[17] Gibbs, T. (2000). Detailing for Hurricanes. https://www.oas.org/pgdm/document/mhbdc/b3_text.pdf
[18] Taher, R. (2007). Design of Low-Rise Buildings for Extreme Wind Events. Journal of Architectural Engineering. 13: 1

3.2.2. Identification of Barriers for Roof Pitch Angle

3.2.2.1. Economic and Financial Barriers

Cost

Steep roofs are more expensive than regular roofs due to the larger surface area, which requires additional construction materials. The increased cost to prospective owners of both additional material and extra labour hours is a substantial disadvantage. There are minimal incentives for upgrading current roofing facilities since the payoff on this technology is not immediate, while consumers are not likely to upgrade roofing structures if there is no issue with the existing structure.

Table 40 provides a comparison of the roof area and additional costs associated with a steeper roof pitch, from 6/12 to 8/12. Notably, construction costs differed by a far larger margin than surface area would imply. In this instance, the surface area is taken as a proxy for the additional material used, with an increase of approximately 8%. The cost, by contrast, is 34% higher for the steeper roof. These additional costs are also partially due to the necessary wood materials for the rafters of the roof.

Table 40: Comparison in construction costs for roofs at differing pitches on a 3-bedroom residential structure[19]

Roof Pitch	Roof Area/ft^2 [20]	Cost/XCD	Cost/USD
6/12	1395	$58,600	$21,700
8/12	1500	$78,600	$29,000

3.2.2.2. Non-financial Barriers

Status quo bias

Stakeholders indicated that the general public is not aware of the benefits of steeper roof pitch angles, which makes it less common in the modern era. Residential homeowners lacking the knowledge of the benefits of this technology have not incorporated it in their roof plans.

Housing trends will take time to incorporate the steep roof pitch angle into common design practice. For the past 70 years, the pitched angle roof has fallen out of favour, and as such, an entire generation will have lost touch with this distinct roofing style. Integrating it into everyday practice once more will not happen overnight and will require a concerted effort on the part of policymakers to influence public opinion. Providing new homeowners and construction

[19] Assumptions provided by consultation with local architect. Construction costs extracted from consultant modelling of National Housing Development & Urban Renewal Co. Ltd, project. House is single floor 3bedroom, 2-bathroom, 1265 sq. ft with hip roof
[20] Estimated based on floor surface area using online tool: https://www.omnicalculator.com/construction/roofing

tradespersons with evidence of the benefits of steeper roof pitches will go a long way in facilitating the diffusion of this technology.

Lack of awareness and information for contractors

Industry professionals advised that the information and awareness of contractors such as technicians, carpenters, and architects on the design of steep roof pitch angles is a barrier to its diffusion. Due to the transition away from this roofing style, younger tradesmen are not exposed to this form of roof framing. The lack of expertise and experience in this form of framing is exacerbated by the concentration of skills in older tradespersons, who are unable to do the work themselves. Bridging this generational gap is critical to the acceptance of this technology across the industry. In addition, the lack of buy-in from professionals in construction limits the use of steep roofs.

3.2.3. Identified Measures

3.2.3.1.1. Economic and Financial Measures

Capital

The costs for constructing steeper roofs can be set off by reducing insurance premiums for houses using this more resilient design style. Buy-in from the financial sector is necessary for the full implementation of this solution.

3.2.3.2. Non-financial Measures

Status quo bias

The public also needs to be made aware of the substantial resilience benefits of steeper roof pitch angles. Informative seminars and public media campaigns can be used to inform the public on the usefulness of this design style. This public media campaign can include radio, newspaper and television advertisements and interviews.

Targeted seminars for industry professionals can facilitate buy-in and diffusion of this framing style in the market. For these seminars to reach the right audience, they can reach out to construction companies with ongoing building projects. Additionally, the National Housing Development and Urban Renewal Co. Ltd can be targeted as a major local developer.

Roof material installation

Standards need to be created or adapted to guide construction workers on ensuring the quality of the materials that are being used in the construction of the roof[21]. Training for younger contractors

[21] Gibbs. 2000. Detailing for Hurricanes. https://www.oas.org/pgdm/document/mhbdc/b3_text.pdf

can be administered as a component of the TVET programme, which will include an assortment of trade and technical training opportunities. However, this training programme will need to be integrated into a larger project for certifying construction workers and tradespersons. For professionals who need special training, workshops on steep roof pitches are the best approach. These workshops can be organized through large contractors who can bring on smaller-scale contractors. The logical analysis for this technology is detailed in Annex H.

Table 41 provides a cost breakdown of a method to increase the diffusion of the technology through a pilot program with training and awareness campaign.

Table 41: Pilot Project components for Roof Pitch Angle

Project Component	Timeline/yrs	Cost/USD
Public Awareness Campaign	1	$2,000
Public Service Announcements	1	$3,000
Seminars	1	$1,000
Training programme roofing	3	$26,000
TOTAL	3	**$32,000**

3.3. Barrier Analysis and Possible Enabling Measures for LED Lighting

3.3.1. General Description of LED Lighting

Lighting is an essential need in all buildings for proper functionality. Individually, a light bulb consumes a small amount of energy in relation to the overall energy consumption of a building. However, depending on the number of lighting fixtures and technology in the building, it can result in a high energy consumption for that building. Lighting is reported to be responsible for 19% of energy consumption worldwide (Gago et al., 2015). In 2020, an energy audit of the VC Bird International Airport revealed that lighting consumed approximately 19% of the energy of the airport, which was an area that is being targeted for reduction by using energy efficiency measures (CBCL, 2020).

Since the advent of the incandescent light bulb, there have been several advancements in lighting technologies aimed at reducing the energy requirement of light bulbs. This led to the creation of commercial light-emitting diodes (LEDs) light bulbs that have higher efficiency (uses less energy to produce a given quantity of lumens, *(see Table 42)* than other lighting technologies with one main drawback being more expensive. The price of LED has been decreasing rapidly over the years due to the improvement in manufacturing and increased demand. In 2011 LED bulbs cost between USD45-50, which fell to less than USD 10 by 2018.[22]

[22] https://www.ledinside.com/news/2018/8/global_led_lighting_products_price_trend

Table 42: Rule of thumb for determining the equivalent wattage of LED light bulbs for a different light technology[23]

Type of Light Bulbs	LED equivalent wattage conversion factor (%)	Example	
		Traditional	LED
Incandescent	10	60W	6W
Compact Fluorescent Lamp CFL	50-60	20W	12W
Halogen	15	75W	11W
High- and Low-Pressure Sodium	~50	250W	100W
Metal Halide	~50	400W	200W

Using the GACMO model (Annex I), an estimate was made for the implementation of 20,000 LED bulbs. Replacing 60W incandescent lights with 8W LED bulbs would reduce the electricity demand from 3504MWh annually to 467MWh annually. There would also be an estimated reduction in CO2 emissions by 8039.28-ton CO2 eq.

Transitioning away from high energy-consuming light technologies such as halogen, and incandescent light bulbs to LEDs provides several benefits to a household on a small scale and a country on a larger perspective. For a country like Antigua and Barbuda that uses mostly imported fossil fuel to generate electricity, aggressive adoption of LED technology has the possibility of reducing oil importation if widespread adoption is achieved leading to the reduction of GHG emissions. Additionally, if the sources of energy were renewable energy, this would add to the energy efficiency effect of LEDs. For a household, benefits are less replacement due to LED long life span of over 10 years and reduced electricity bill leading to more disposal income.

3.3.2. Identification of Barriers for LED Lighting

3.3.2.1. Economic and Financial Barriers

Cost

LED bulbs typically cost more than the lighting technologies, with average prices in Antigua and Barbuda between $20 – 25 XCD ($7-9 USD) for a unit. Compared to incandescent lighting, this price is 20 times higher, which is a significant difference, even at these relatively low upfront costs. Some light bulbs replacements may also require that the lighting fixture is upgraded to accommodate the LED light bulb, which increases the cost of the transition. A home conversion, using roughly 6 bulbs, would require $120 in additional spending, a cost that may seem impractical if the long-run benefits are not clear. A comparison (Table 43) below of LEDs against incandescent

[23] https://ledhut.co.uk/blogs/news/led-equivalent-wattages-against-traditional-lighting

and CFL options shows its feasibility as a wiser investment option, even with the higher initial investment required.

Table 43: Cost comparison between LED, and Incandescent and CFL Lighting Options used for 8 hours a day[24]

	LED	Incandescent	CFL
Wattage	8	60	15
Average rated Lifetime / hours[25]	50,000	2,000	20,000
Expected life expectancy/ years	17.1	0.68	6.85
Cost of Replacement/XCD	$20.00	$1.00	$15.00
Annual cost per year/XCD	$23.36	$175.20	$43.80
Cost Comparison to LED			
Savings per year/XCD		$151.84	$20.44
Payback Period/yrs		0.1	1.0
Energy saved over lifetime /XCD		$2,600.00	$350.00

3.3.2.2. Non- financial Barriers

<u>Lack of knowledge about eco-innovative products such as LEDs</u>

Consumers' lack widespread knowledge and information about the eco-innovative benefits of LEDs light bulbs. This reduces the diffusion of these products. Generally, fluorescent, and incandescent bulbs are purchased due to the price and familiarity. Consumers' choice of not transitioning to LED lighting is influenced by their limited mechanism of only comparing the initial cost of the bulbs rather than looking at the overall return on investment in the technology.

<u>Lack regulations</u>

Presently there is no policy to regulate the quality of LED light bulbs entering the island which can significantly damage customers' trust in the technology. Moreover, the lack of a policy to ban the importation or the phase-out of low efficiency light bulbs is a barrier to the high uptake of LED light bulbs.

3.3.3. Identified Measures

3.3.3.1. Economic and Financial Measures

<u>LED distribution drive</u>

The energy and cost savings from LED light bulbs should be better publicized for consumers. Government campaigns would be required for energy efficiency to shift consumption patterns and help to deepen the value of energy-efficient lighting in financial terms.

[24] Prices obtained from 3 local hardware stores
[25] https://www.thelightbulb.co.uk/resources/light_bulb_average_rated_life_time_hours/

The Government, in collaboration with APUA can create an initiative that distributes LED light bulbs to homeowners (especially fuel poverty households) in exchange for their older light bulbs. To cover the cost of the light bulbs, grant funding through climate initiatives can be acquired to provide the led bulb swap at no cost to the consumer (Witt et al., 2019). Another solution would involve the utility company creating a program where they recover the cost of the bulbs from the consumer over an agreed-upon time frame through a small fee on their light bills. Surveys will be collected pre and post the program to assess the consumer's perception of energy-efficient investment. Moreover, the reduction in GHG emissions can be calculated using the information collected. Another aim of the initiative would be to promote energy conservation in general and teach consumers about identifying energy-efficient appliances.

3.3.3.2. Non-financial Measures

Consumers' lack knowledge about LED products

To overcome these barriers, measures should be implemented such as advertising campaigns to raise awareness of the LED bulbs to employees and businesses, as well as large scale distribution of this eco-product to small scale businesses and households. At the point of the sale of LED light bulbs, signage will be placed where the LED is being sold to help the consumer make a more informed decision. Signage should be endorsed/created by reputable agencies such as the Bureau of Standards or the Ministry of Energy to give customers confidence in the information presented. In addition, an energy awareness campaign can be held in each parish at central locations to promote and teach consumers about cost and energy savings for the use of energy-efficient technologies such as LED light bulbs. Based on similar campaigns of this magnitude and importance, it is estimated that this would take two years at a cost of USD45,000.

In addition, efficient technologies from other sectors such as those in the water section of this document could be integrated into this campaign to create a comprehensive understanding for the public of the capabilities of the various technologies.

Implement regulations

The global marketplace is filled with various brands of LED light bulbs, some of which are of inferior quality[26]. Consumers, therefore, need to be protected from these low-quality products through strategic policies and the screening process. The implementation of a policy that has clearly defined performance standards for imported LED light bulbs such as a minimum efficiency, an enforcement body that tests and monitors LED light bulbs for compliance with standards. The policy should include a robust environmental management plan for the end-of-life disposal of light

[26] https://www.waveformlighting.com/home-residential/why-your-lighting-looks-bad-5-potential-reasons

bulbs, especially for those with toxic elements. Lastly, the policy should speak to the phase-out of low efficiency light bulbs to increase the uptake of high efficiency/low energy consuming light bulbs. The policy could investigate the phase-out of low efficiency light bulbs such as incandescent light bulbs. Feasibility studies and surveys should be used to inform the drafting of the policy and legislation to ensure favourable acceptance.

The logical analysis for this technology is detailed in Annex J.

3.4. LINKAGE OF THE BARRIERS IDENTIFIED

The roof pitch angle is an adaptation technology, and the LED is a mitigation technology. Even though technologies are listed under the building sector, they offer different advantages to climate change. ~~Due to this and varying barriers of implementation for the technologies. However,~~ B~~b~~ased on the stakeholder workshop, the challenges for the technologies in the building sector are~~is~~ affordability, information and awareness. Therefore, these constraints result in lack of consumer awareness, established pricing scheme, and reduced demand for the technology.

Public information is critical for the diffusion of LED technologies. The lack of knowledge of LED's potential energy savings limits its diffusion. One can surmise that there is a need for an emphasis on the energy efficiency and benefits of LEDs, which would improve the efficiency of existing and new buildings.

In addition to the issue of public awareness, the high investment cost of these technologies limits their use by the wider populace. Undoubtedly, there is a need for buildings (both residential and commercial) to reduce their energy consumption to mitigate against using excessive amount of fossil fuels to meet their electrical demands. High costs, however, remain an issue that limits the diffusion of these goods, despite the benefits.

3.5. ENABLING FRAMEWORK FOR OVERCOMING THE BARRIERS IN BUILDING SECTOR TECHNOLOGIES

Table 44 Enabling Framework for LED Technologies

BARRIERS	MEASURES	BENEFITS	TIME FRAME & COST	AGENCY | ENTITY
High cost	▪ The government in collaboration with APUA can create a program that distributes LED light bulbs to homeowners (especially fuel poverty households) in exchange for their older light bulbs	▪ Higher implementation of technologies by the public results in lower energy consumption of buildings, as a result, reduces electricity bills and energy demand.	▪ LED 2 years USD245,000	- Department of the Environment - APUA - ABBS
Lack of information and awareness	▪ Disseminate information by the ABBS Energy website on energy efficiency measures and protocols.	▪ Enhanced public knowledge of technologies applicability and their benefits.	▪ LED 2 years USD 45,000	- Antigua and Barbuda Bureau of Standards - Department of the Environment - Government of Antigua and Barbuda - APUA

Table 45 Enabling Framework for Roof Pitch Angle Technologies

BARRIERS	MEASURES	BENEFITS	TIME FRAME & COST	AGENCY | ENTITY
High cost	▪ Encourage financial institutions to provide climate-proofing low-interest rate loans.	▪ Increasing climate adaption technologies would lower the probability of damages after a natural disaster (eg. CAT 5 hurricanes).	• Roof pitch Angles 2 years USD 103,260	- Department of the Environment - Antigua and Barbuda Investment Authority ABIA - Development Control Authority - National Housing Development and Urban Renewal Authority - Financial institutions
Lack of information and awareness	▪ Increase awareness for technologies such as roof pitch angles, by having informative sessions like seminars, for contractors and local community members on innovative housing techniques.	▪ Reduced number of roofs on buildings to be replaced after a hurricane.	▪ Roof Pitch Angle 2 years USD 103,260	- Development Control Authority - Antigua and Barbuda Bureau of Standards - Department of the Environment - Government of Antigua and Barbuda - Construction agencies

4. TRANSPORT SECTOR TECHNOLOGIES

4.1. PRELIMINARY TARGETS FOR TECHNOLOGY TRANSFER AND DIFFUSION

A summary of the preliminary targets for the five-priority technologies for the transport sector is represented in Table 46 - Table 49.

Table 46: Preliminary Target for Electric Vehicles

Technology	Electric Vehicle
Primary target	The government fleet transitioned to all-electric by 2035
Required investment	Government fleet of 1,100 vehicles to be replaced. Average cost per vehicle USD 50,000 Estimate total USD 55 Million
Expected lifetime	15 years
Expected economic benefits	Overall reduction for maintenance with a reduced fuel cost and operations;
Climate change impacts	Estimated reduction in emissions of 924 tC02-eq when the fleet is transitioned. Assuming the electricity is produced with fossil fuel. If renewable energy is used a total of 2300 tC02-eq reduction could be observed

Table 47: Preliminary Target for Solar Charging Stations for Electric Vehicle

Technology	Solar Charging Stations for Electric Vehicles
Primary target	150 level 2 solar charging stations installed across government buildings for the transition of the vehicle fleet by 2035.
Required investment[27]	A level 2 solar charging station is estimated at USD14k-23k Total investment for 150 stations- USD 2-3.5 Million[28]
Expected lifetime	25 years for the solar panel and 10+ years for the battery system
Expected economic benefits	Each solar charging station is estimated to save USD 3000 annually. Therefore, a total of USD 450,000 reduction in electricity cost annually for the 150 stations
Climate change impacts	For a total reduction of 1,182 tC02 eq

Table 48: Preliminary Target for Efficiency in the Transport Sectors

Technology	Efficiency in the Transport Sector
Primary target	Revised Vehicular emission standards and import regulations for the new and used car market to reduce annual GHG emissions by 2030.
Required investment	USD 1,222,750
Expected lifetime	Indefinite
Climate change impacts	Reduction of 133,300 tC02 eq annually

[27] See Appendix D
[28] Stakeholder consultation with Megapower Antigua Ltd

Table 49: Preliminary Target for Improved Road Infrastructure

Technology	Improved Road Infrastructure
Primary target	All Saints Road 8.4km improved by 2030
Required investment	~ USD 19.9 Million
Expected lifetime	10 years
Expected economic benefits	To be determined from a feasibility study – tentatively: Time Savings, reduced vehicle maintenance costs, reduced road maintenance costs
Climate change impacts	Increased structural resilience to flooding from 1-in-50-year occurrence events and hurricanes: Adequate stormwater runoff, less deterioration, no fallen lines

4.2. BARRIER ANALYSIS AND POSSIBLE ENABLING MEASURES FOR IMPROVING ROAD INFRASTRUCTURE

4.2.1. General Description of Improving Road Infrastructure

Road infrastructure can be improved to provide adaptation benefits to climate change. Appropriate road infrastructure improvements are advantageous in building resilience to disasters and their effects. In the case of Antigua and Barbuda, hurricanes, sea-level rise, flooding and droughts can have severe effects on critical road infrastructure and utilities. The following attributes will be considered under this technology to constitute 'improvements':

1. Road geometry that creates a smooth transitional use of vehicular traffic, pedestrian safety and alleviates flooding.
2. Adequately sized open and closed conduit drains to accommodate heavy rainfall events.
3. Buried electrical and telecommunications lines to reduce hazards associated with fallen lines post-tropical storm.
4. High-Density Polyethylene (HDPE) pipes in place of PVC pipes. HDPE pipes can withstand higher pressures, have the best joint pressure resistance, are more heat resistant and can dampen and absorb shock waves.
5. Increased base thickness of roads which requires less maintenance, manages rainfall better and reduces road deformation.

Antigua and Barbuda has recently executed two major road infrastructure projects: the Road Infrastructure Rehabilitation Project and the Second Road Infrastructure Rehabilitation Project. Both projects were financed in part through loans obtained from UKCIF through the Caribbean Development Bank and were executed by the Ministry of Works and Housing (MOWH).

The Road Rehabilitation Project began in 2016 and will rehabilitate 8.7 km of major road along Friars Hill Road and the Sir George Walter Highway. It is currently being finalized. The Second Road

Infrastructure Rehabilitation Project upgrades 27.76 km of the roadway as follows: 1.44 km of Anchorage Road (AR), 14 km of Sir Sydney Walling Highway (SWH), 2.9 km of Old Parham Road (OPR) and 9.45 km of Valley Road (north) (VRN). These projects have set an effective precedent for further road infrastructure improvements.

4.2.2. Identification of Barriers for Improving Road Infrastructure

4.2.2.1. Economic and Financial Barriers

High Capital Cost

Road infrastructure improvements are, by nature, costly and capital intensive. Most of the roads in Antigua and Barbuda do not meet the criteria described in this technology and improving them to suit will be costly. Similar road infrastructure improvements have been implemented in the two Road Infrastructure Rehabilitation Projects, which were both financed through loans from the Caribbean Development Bank (Caribbean Development Bank, 2017). Table 50 illustrates the prices of road infrastructure improvements in the two ongoing projects.

Table 50: Cost of Prior Road Infrastructure Projects in Antigua and Barbuda

Project	Length of Road/miles	Total Cost/USD	Cost per mile/USD
Second Road Rehabilitation Project	17.25	$65,627,000	$3,800,000
Road Infrastructure Rehabilitation Project	5.41	$30,630,000	$5,666,000

Antigua and Barbuda lacks the fiscal space to fund major road renovations independently. The limited tax base of 752 million XCD[29] (2019), which is largely committed to expenditures on wages and social services, cannot provide the capital for road repairs. Both major infrastructure projects received development assistance in the form of grants and development loans. For instance, the Road Infrastructure Rehabilitation project was contingent on external financing from the UKCIF to the tune of £14 million (~19 million USD) of the total project funding.

4.2.2.2. Non-financial Barriers

Lack of Proper planning and maintenance-

Stakeholders including financiers, politicians, planners, transport agencies, organizations and individuals living in transport zones, are not always engaged in road infrastructure. Moreover, stakeholders have indicated that there is a need for proper planning and oversight of infrastructure projects.

Public Concerns – delays and disruptions

[29] https://ab.gov.ag/pdf/budget/2019_Antigua_Estimates.pdf

The public is often apprehensive about the implications of road infrastructure projects. The fear of flooding after the rising of road surfaces can cause a backlash against the project moving forward (Harris, 2020). The possibility of dislocation of local business and community services is also a barrier to infrastructure improvements. Traffic and business disruptions result in a decline in economic activity and a loss of revenues. Blockages to major roads cause traffic congestion and limit access to businesses located in the vicinity. In addition, road works can disrupt telephone, electricity, and water supplies, affecting communities and business in surrounding areas. The wider public's apprehension about road improvements stems from concerns about delays in project completion and prolonged disruptions to traffic flows.

4.2.3. Identified Measures

4.2.3.1. Economic and Financial Measures

Accessing concessional finance

While road infrastructure projects are typically capital and resource-intensive, the best path to accomplishing substantive upgrades is through concessional finance which is given with an understanding of the resilience and adaptation benefits of these upgrades. Antigua and Barbuda possesses a reliable track record of accessing development finance from both multilateral funds and through bilateral agreements. It is important to enhance the ability of government bodies such as the Ministry of Works (MoW) to access finance for critical road projects. The Second Road Infrastructure Rehabilitation Project facilitated the formation of a Project unit at the MoW, a first step that should be built on to improve the capacity to implement projects and manage funds from external sources.

4.2.3.2. Non-financial Measures

Public Concerns – delays and disruptions

Recent road improvement projects have resulted in enhanced road conditions and increased resilience. The success of these projects should be publicized to assuage concerns about delays and disruptions due to infrastructure projects. In addition, comprehensive feasibility studies which incorporate lessons learned from the previous projects will improve the rate of roadworks. By capitalizing on the experience of the prior road projects, the responsible government agencies can streamline the process and circumvent possible delays and risks.

Lack of Proper planning and maintenance-

Proper planning to inform stakeholders is vital to ensure buy-in. It is important to engage the various sectors of the population in discussion at all stages. The creation of a project management team tasked with managing major road infrastructure projects is a possible solution. This team can work in conjunction with relevant government ministries and statutory bodies to ensure that all relevant stakeholders are consulted and included. Furthermore, this team will be able to operate in a dynamic role and can be held accountable for all tasks related to road infrastructure.

Feasibility Study

Infrastructure improvements along major roadways will be beneficial in the long term. Critical roadways are viable options for infrastructure improvement. A feasibility study is required to determine the suitability of this proposed road improvement. Key elements needed in a feasibility study will include:

- Traffic Studies – 24-hour annual daily traffic
- Traffic forecasts – based on GDP growth, population growth, vehicle ownership rate, traffic growth.
- Vehicle Operation Costs (VOC) – vehicle costs, tyre costs, maintenance costs
- Time savings – congestion effects and value of time (VOT)

The study should factor in climate resilience into the EIRR of the proposed improvements. These elements will then be used to forecast the value of the project for road users and the government as opposed to the costs of the renovation. Tentatively, a project as such could have costs outlined in Table 51.

Table 51: Project Components for Improvement of Road Infrastructure

Component	Timeline (yrs)	Cost (USD)
Feasibility Study[30]	1	$200,000
Infrastructure improvements[31]	3	$19,700,000
TOTAL	4	$19,900,000

4.3. BARRIER ANALYSIS AND POSSIBLE ENABLING MEASURES FOR ELECTRIC VEHICLES

4.3.1. General Description of Electric Vehicles

There is a global trend towards the adoption of electric vehicles as a means of reducing GHG emissions. This trend has gained momentum in Antigua and Barbuda, thanks in part to experiences in Barbados, the dramatic reduction in prices and grant finances available to the DOE. The consistent advocacy for this green technology is in keeping with the Government's agenda to eliminate fossil fuel dependency. In 2011, CO2 emissions in the transportation sector accounted for 30%[32] of the country's GHG emissions; this figure can be drastically reduced through the introduction of BEVs across the transportation sector. Under the revision process for Antigua and

[30] Retrieved from comparable feasibility studies for prior road infrastructure projects
[31] Approximated based on Table 51
[32] https://www.worldometers.info/co2-emissions/antigua-and-barbuda-co2-emissions/

Barbuda's Nationally Determine Contribution, a full transition away from internal combustion vehicles to electric vehicles is currently under consideration.

Some electric vehicles have the capability to allow the energy stored in batteries to be used to power a home or any other load. This is a game-changing feature for a renewable energy system as it reduces the need for large battery storage at home. By installing a bidirectional charging station, electricity can flow from a home into the vehicle and be retrieved from the vehicle in power outages[33].

The International Energy Agency (IEA) reported that almost 3 million electric vehicles were sold in 2020. This results in approximately 10 million electric vehicles global on the road. There was also a noticeable growth in the number of electric buses and trucks to 600,000 and 31,000 respectively[34]. The EV market in Antigua and Barbuda is small with approximately 40 EVs reported as a part of the vehicle fleet (54,000 ICE vehicle) as of 2021. Three of the 40 EVs (2 sedans and 1-panel van) are located at the Department of Environment in Antigua along with 2 charging stations. To lead by example, the Government intends to transition its 1,100 vehicles to electric by 2040.

The cost of operating an electric vehicle, despite the high cost of electricity on the island, is estimated to be 22% cheaper in fuel cost than operating an ICE vehicle *(Table 52)*. Another area that one can experience savings is in maintenance. Electric vehicles require less maintenance than that an ICE vehicle due to fewer moving parts. Furthermore, EV does not have the usual parts that need to be replaced such as spark plugs, air filter, and oil change. Moreover, brake pads are replaced less frequently as they are designed to take advantage of regenerating breaking technology. It is estimated that maintenance of an EV conservatively could cost 20%, while other studies give a more aggressive reduction of 65% than that of an ICE vehicle (Lebeau et al., 2013).[35]

Table 52: Operating cost comparison between an EV and an ICE using average efficiency for sedan vehicle in 2020

Parameters	Type of Vehicle	
	ICE Vehicle	EV Vehicle
Distance travel/month (miles)	466	466
Cost of gasoline/gallon (XCD)	$12.50	-
Cost of electricity per kWh (XCD)	-	$1.00

[33] https://blog.wallbox.com/en/why-bidirectional-charging-is-the-next-big-thing-for-ev-owners/
[34] https://www.iea.org/reports/global-ev-outlook-2021
[35] https://www.edfenergy.com/electric-cars/maintenance

Parameters	Type of Vehicle	
Average Vehicle efficiency	3.1gallons /100miles[36]	30kWh/100 miles[37]
Operating cost /month XCD	$180.6	$139.8

4.3.2. Identification of Barriers for Electric Vehicles

4.3.2.1. Economic and Financial Barriers

The financial cost of the EVs has prevented the penetration of this technology into Antigua and Barbuda's transport market. A new EV cost on average USD 50,000 to purchase on the island. Despite the growth of their stock worldwide over the past decade, the cost of an EV is still very high compared to the ICE alternative, available in the used car market. Moreover, new EV owners will need a home charging system with all associated charging infrastructure which increases the cost of ownership (at the current time of this document being prepared). EV diffusion faces a major stumbling block without a supportive network of charging facilities to reduce the cost of ownership.

Used Car Market

Antigua and Barbuda has a very active used car market with no age limit on car importation. Figure 5 shows that vehicles between 1997 and 2010 account for most of the private vehicle fleet. To further understand the vehicle market, the vehicle fleet was broken down into the most popular car models on the island. A cost comparison was then done between importing the identified popular car models versus importing electric vehicles (new and used). Table 53 captures the results of the cost comparison and highlights the price chasm between used vehicles being imported and the cost to import electric vehicles from the Japanese car market. The prices of used ICE vehicles are too low for EV vehicles to be competitive. Additionally, with no differential tariff for EV vehicles, when they arrive in the country, taxes and duties maintain the divide between a used EV and a used ICE. The price of new ICE vehicles (the popular models on the island) is still not comparable to used electric vehicles using the Nissan leaf, as an illustration, see Table 53.

Table 53: Displays the cost difference between aged used vehicles for both EV and ICE vehicles that can be purchased from Japan and delivered to St John's in Antigua before taxes and duties are applied[38].

Used car over 5 years old (USD)	Used car less than 5 years old (USD)
Nissan leaf X 2013, 22.8km Mileage Vehicle price 6,359 Freight RORO 2,350 Insurance: 87 Total 8,796	Nissan Leaf 2018 7km mileage Vehicle price 22,126 Freight RORO 2,350 Insurance: 247 Total 24,723

[36] https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=42013
[37] https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=42562
[38] https://www.sbtjapan.com/

Used car over 5 years old (USD)	Used car less than 5 years old (USD)
Toyota Vitz 2007 50km mileage Vehicle price 990 Freight RORO 1,800 Insurance: 30 Total 2,819	Toyota Vitz 2018 6.7km Mileage Vehicle price 8,456 Freight RORO 1,800 Insurance: 103 Total 10,359
Honda fit 2010 27km mileage Vehicle price 870 Freight RORO 1,800 Insurance: 29 Total 2,699	Honda fit 2018 8km mileage Vehicle price 9,160 Freight RORO 1,800 Insurance: 112 Total 11,272
Suzuki Swift 2007 55km mileage Vehicle price 910 Freight RORO 1,800 Insurance: 29 Total 2,739	Suzuki Swift 2018 9km mileage Vehicle price 6,320 Freight RORO 1,800 Insurance: 83 Total 8,203

Current Import Standards

The current import tax on vehicles includes an Environment Levy, applied as follows:

- Vehicles up to 1-year-old a rate of XCD1,000.00
- Used vehicles over 1-year-old XCD 4,000.00.

This levy is meant to pay upfront the cost of solid waste disposal for the vehicles. The higher cost for the older vehicles recognizes that these will be more frequently disposed of due to age. The cost of disposal is the same even if it is an old or new vehicle. The battery in an electric vehicle can be repurposed at its end of life to act as a backup storage power for buildings. Electric vehicles are unlikely to benefit from a full reduction in Environmental Levy given that other parts of the vehicles other than the battery require disposal.

4.3.2.2. Non-financial Barriers

Limited Local Suppliers

Currently, Megapower Antigua Ltd is the only local supplier of electric vehicles, limiting the options available to the consumer. Authorized sellers of well-known car brands offer limited model variety, none of which are EVs. The low availability of models of EV worldwide as well as the ability to service the vehicles in Antigua and Barbuda does not incentivize authorized sellers to stock them or their parts.

Infrastructural Limitations

There are insufficient public charging facilities for EVs in Antigua and Barbuda. There are only two public charging station located at Epicurean and Nelson's Dockyard. There are a few private stations located at Government offices such as the Department of Environment, and the Sir Vivian Richards Stadium. The chargers at the stadium are used for charging the two electric school buses. Also, there are several private solar charging stations at the Canada Place business complex located in St John[39] The limited options available constrain the charging options for potential new EV owners who may not be able to charge at home.

Limited Skilled Personnel

There is a limited of personnel for the maintenance and repair of EVs. There is only one certified electric car shop on the island. Additionally, there is no vocational training programme for mechanics to learn about EVs and their operations.

Public Awareness

Insufficient information about a product can lead to reduced market adoption. Therefore, communicating accurate information to the public is critical to aid the diffusion of EVs. Potential users' mindfulness of the benefits of an EV, monetary motivations, sufficient charging and foundation accessibility, and potential saving compared to fuels are basic components affecting the diffusion of EV.

4.3.3. Identified Measures

4.3.3.1. Economic and Financial Measures

Lower Investment Cost

To reduce the cost of EVs, there are several possible measures. Subsidies for these vehicles, alongside tax exemptions and avoided registration costs, are actions taken by developed countries. However, Antigua and Barbuda is not in a position to utilize these measures. Several countries have adopted the following regulatory incentives to increase the uptake of EV:

- Norway implemented a targeted incentive for business by reducing car tax to 50% on company cars[40]
- Vehicle tax breaks for purchasing of EV was practiced in Norway and the state of Georgia in the USA.
- A scrappage scheme for ICE- developing a program where persons can recover the cost of the ICE vehicle can encourage persons to transition to an electric vehicle[41]. This can be

[39] https://canadaplace.ag
[40] https://www.c40knowledgehub.org/s/article/How-to-drive-electric-vehicle-uptake-in-your-city?language=en_US
[41] https://www.c40knowledgehub.org/s/article/Survey-of-best-practices-in-reducing-emissions-through-vehicle-replacement-programs?language=en_US

used to phase out the public-private bus system by implementing an age limit on vehicles being used to transport passengers and allow persons to use their present vehicle to offset the initial capital cost.

The use of fiscal measures to support EV adoption is improbable in Antigua and Barbuda. A more viable solution would be a legislative approach by banning the importation of ICE vehicles.

4.3.3.2. Non-Financial Measures

Skilled personnel

With government support, the vocational schools that train mechanics can be engaged to create an electric vehicle curriculum. Teachers will need to be trained and certified to teach the curriculum. Other local mechanics can be encouraged to partake in these training programs to enhance their knowledge. Teaching aids at vocational schools must be upgraded to international standards training equipment.

Health and safety personnel and first responders will also need to be trained to respond to incidents that involve electric vehicles. Custom agents also will need to be trained to identify the different types of electric vehicles and apply the necessary levies on the vehicles. The cost for this training program will require equipment, development of a curriculum, training of teachers and current mechanics through a just transition framework over 5 years. The estimated cost for such an undertaking is estimated at a minimum of USD 500,000.

Regulation of the used car market

The used car market can be regulated in the following ways:

- develop a complementary policy framework to introduce import standards for used electric vehicles that considers a combination of the following parameters: age, mileage, and battery state of health.
- ban the importation of all ICE vehicles

Other measures for regulating the available used car fleet are presented below under the efficiency in the transport sector.

Public awareness and information

Options to improve public awareness include workshops for the public and private sectors such as EV car shows and webinar informative series in addition to a public campaign to guide installers, car dealerships and users on how to maintain and charge EVs. The car manufacturers can be engaged in carrying out awareness campaigns on their product. One of the aims of the campaigns will be to dispel any uncertainty in consumers mind regarding the total cost of ownership by educating them on calculating the operating and maintenance of the vehicle. The awareness program can be carried out over 2 years at an estimated cost of USD 6,000.

Infrastructural limitations

In addressing the challenges related to limited charging infrastructure, a public procurement initiative will facilitate the more widespread availability of these stations. Partnerships with current gasoline and diesel providers to transition existing facilities can improve the availability of charging stations. Public-private engagement is necessary to ensure that key players in the current transport sector are supportive and can play a role in a transition to EVs.

Policy regulation would need to be created to ensure that locally appropriate tariff is applied to charging stations. Moreover, to ensure that the gas stations owners can offer solar charging electric vehicle services, the Public Utility Act (1973) will need to be revised to give companies other than the national utility company APUA the ability to sell electricity for the charging of cars. Lack of public charging infrastructure will be addressed by complementary technology diffusion of Solar Charging Stations. Further information on this technology is explained below.

The logical analysis for Electric Vehicles is detailed in Annex K.

4.4. BARRIER ANALYSIS AND POSSIBLE ENABLING MEASURES FOR SOLAR CHARGING STATION

4.4.1. General Description of Solar Charging Station

An Electric Vehicle Autonomous Renewable Charger (EV ARC) is fully autonomous and provides renewable electricity for EVs in public areas. Solar is one of two renewable energy sources which is 100% sustainable and is consistently available due to local climatic conditions. It is important to note that the charging stations are also climate friendly as they do not produce any CO_2 emissions. electric vehicles must be charged via "Green" electricity to achieve the GHG reduction benefits, which is why solar charging stations are being explored.

There are three types of charging technology for electric vehicles that are ranked based on their power output.

- Level 1 charging technology uses 120V alternating current to charge EVs. This is the slowest charging technology that can deliver between 3.5 and 6.5 miles of range per hour.
- Level 2 charging utilizes 240V AC to recharge an EV. This provides faster charging than a level 1 supply power between 3kW and 20kW to the battery. This charger can add between 14 and 35 miles of electric range per hour of charging.

- **Level 3** otherwise called DC fast charging requires the least time in recharging your EVs. Chargers require between 20 and 50kW of electricity that can charge can add an average of 178 miles of electric drive per hour[42].

4.4.2. Identification of Barriers for Solar Charging Station

4.4.2.1. Economic and Financial Barriers

Low demand for EV charging stations

Currently, there are limited numbers of EVs operating in Antigua and Barbuda. The small EV market is linked primarily to the importation of much cheaper used cars as well as the much higher cost of the EV and the perceived high cost of charging with the local utility company. Therefore, the demand for charging stations needed at this time is low in the current transport climate. As a market provided good, this will require concurrent strategies to encourage EV uptake and reduce charging costs. Private investors are unlikely to take the high risks associated with this technology in the current context.

Costs

Level 2 charging stations are the most suitable to be installed in workplaces due to charging speed and power requirement. The average cost for installing a level 2 solar charging stations was estimated during the stakeholder workshop at USD14,000-23,000. The cost is expected to vary depending on the foundation pillars and the supporting structure for the panels that may be needed to be constructed. To add battery storage to the station would require an additional 400-1,000 USD/kWh fully installed. The cost of a standalone solar charging station is a killer barrier for the diffusion of EV, given that its capital investment is ~50% of the vehicle price.

Earning Potential

A 5.4kW level 2 solar charging station which costs USD 28,000 can produce on average 27 kWh per day with 5 hours of peak sunlight in Antigua and Barbuda. This electricity if sold at the current rate of electricity locally (0.37USD/kWh) would be a value USD 9.99. If a company applies a 10% service charge (which is currently being done for the public charging stations), then the total annual revenue is estimated to be USD 4,010. These returns would provide a payback period of approximately 7 years for a level 2 charging station.

4.4.2.2. Non-financial Barriers

Prohibitive Legislation

[42] https://calevip.org/electric-vehicle-charging-101

Presently, gas stations receive fuel from the West Indies Oil Company to meet the fuel needs of the transport sector. The electric vehicles currently on the island have access to two public charging stations (Epicurean Supermarket and Nelson's Dockyard) that are powered by Antigua Public Utilities Authority (APUA). The transition to solar charging stations will switch the gas station into the business of selling electricity. Under the Public Utilities Act, APUA must grant permission to persons to generate and sell electricity. Furthermore, the net billing law states that all electricity generated from solar systems over 5kW must be sold to APUA for 0.20USD/kWh, while electricity received from APUA is purchased at USD 0.37USD/kWh. This would greatly affect the profitability of the business. Moreover, gasoline prices fluctuate based on external market forces which impact prices paid at a gas station. However, the transition to a solar charging station has no external influence on the cost to generate the electricity, therefore regulating legislation will be needed to protect consumers.

Limited Expertise

Solar charging stations are sometimes sold as single units but may also be assembled from constituent parts. To assemble these systems, there is a need for technical know-how about solar panels, electric vehicles, and electrical skills. Due to the small EV and solar markets in Antigua, there are only a handful of companies with professionals who are equipped to assemble such systems. Therefore, this can become a barrier to the fast and large-scale diffusion of this technology when the demand increases.

Variable Output

The output of a solar system is dependent on the time of day and the weather. This will determine the ability of the system to charge vehicles. Moreover, it will control the duration needed to add a given mileage to the vehicle in each given time. Load management expertise will be needed especially if the EV charging system is connected to larger solar that has other loads to feed.

Maintenance

A large public EV charging market will require networking capabilities to operate efficiently and ensure good quality of service. This would be needed to inform customers of the availability of the station while giving the operators an option of monitoring the system. Therefore, routine maintenance of the solar charging station - especially the computerized communication systems - is necessary. Security systems would be needed also to protect against vandalism.

4.4.3. Identified Measures

4.4.3.1. Economic and Financial Measures

Bulk buying

The systems can be installed in locations that will encourage users to utilize them on their journey. For instance, by installing the charging stations at a supermarket, the customer can charge their car while shopping. This gives the owner of the supermarket an avenue to diversify their revenue. If bulk purchase of components leads to reduction in the overall cost of the components of the system, this reduction in the technology's cost would make it a more viable opportunity for the business owners.

Cost

One mechanism that can be used to overcome the capital cost of the solar EV charging systems is to make it a multifunctional system. If these systems are used only to charge EV, then the ROI of the system will be unattractive to business owners. However, if the systems are designed to supply electricity to the building when a car is not being charged then the system will receive more buy-in.

This business model can be marketed to households and workplaces, where the energy generated can be used all the time to meet a load and reduce the electricity bill. A workplace that is opened only Monday through to Friday that has solar systems can use the weekend to charge their vehicle fleet and reduce the quantity of electricity that flows to the grid. The solar system could prioritize the energy needs of the building during the week and selected EV during the week. Households can utilize the same weekend charging scheme for their vehicles, thus reducing the need for a larger solar system to meet their household and vehicle needs. A household could also benefit from vehicle to home technology which would reduce the size of battery they would need by using their car battery for powering their home when needed. Workplaces could gain revenue by giving the public access to their charging stations. The adaptation of this charging scheme can create a market opportunity to start charging station businesses.

4.4.3.2. Non-Financial Measures

Policy Implementation

Framework and Policies that allow private citizens to create a business from charging stations as a source of income. This would mean adjusting the Public Utilities Act to allow citizens to produce and sell electricity. As it stands APUA is the only company that is allowed to sell electricity on the island. Therefore, for gas stations and other businesses to take advantage of solar charging stations, the act must be revised as these businesses will be interfering with the APUA's revenue by selling electricity. This act is especially important for persons that operate gas stations as they will lose customers if they are not able to sell electricity to their electric vehicle customers.

Increase capacity

To increase capacity on the island

- Develop Technical and Vocational Education and Training (TVET) courses at the preferred institution with flexibility for vulnerable persons.
- Combine education with long-term work placements/secondments.
- Contribute to the development of “Train the Trainer” courses to upskill existing trainers to comply with TVET requirements.
- Development of Caribbean Vocational Qualification (CVQ) standards for accredited renewable energy vocational courses.
- Promote regional scholarships such as the North American Board of Certified Energy Practitioners (NABCEP) courses.

Feasibility Studies

Due to Antigua’s small electrical grid, the impact of several solar charging stations on the grid will require grid stability studies, especially for the use of level 3 charging stations. Feasibility studies on solar chargers can be used to investigate:

- Cost of materials and assembly
- Appropriate electricity prices
- Generation potential
- Maintenance and upkeep
- Business models
- Possibility of grid interaction and grid stability studies

Annex L outlines the complete logical analysis for solar charging stations, and Annex M shows the GACMO modelling for the solar charging station uptake.

4.5. BARRIER ANALYSIS AND POSSIBLE ENABLING MEASURES FOR EFFICIENCY IN THE TRANSPORT SECTOR

4.5.1. General Description of Efficiency in the Transport Sector

Antigua and Barbuda’s revised NDC has set “Conditional Mitigation Targets by 2020, to establish efficiency standards for the importation of all vehicles”*.* The implementation of this policy is a notable start towards reducing the country’s GHG emissions as older vehicles are the most significant emitters of GHGs.

The transport sector is heavily dependent on fossil fuel imports. As much as 97.3% of the vehicle fleet is run on gasoline, and the rest is powered by diesel oil. There is a total of 54,891 recorded vehicles in operation in the country, according to the Minister of Transport in 2020. Notably, cars and SUVs make up 90% (49,216) of the country's vehicle fleet, with most vehicles being manufactured between 1990 and 2010 *(see Figure 5 &Figure* 6 *in Annex N)*. The aged vehicle shows great potential for reducing GHG emissions as new ICE cars increased in fuel inefficiency to over 35+MPG (miles per gallon) and the advent of electric vehicles are solutions to significantly reduce annual emissions from the older vehicles if they are replaced assuming the annual miles was 7500 and 8.887kg CO2/gallon for a typical passenger vehicle[43] *(see Table 54).*

Table 54: Estimation of the C02 emission generation from the most abundant type of private fleet in Antigua

Type of vehicle	# of vehicles over 10 years	Avg MPG[44]	Fuel CO_2 eq ktons/ year
SUV	13,278	17.3	50,351
Vans	1,000	17.3	3,792
Cars	20,000	23.5	55832
Total	34,278		109,975

Efficiency standards for imported vehicles is a necessary tool for successfully reducing GHG emissions in Antigua and Barbuda. However, the affordability of used vehicles is a significant barrier to the implementation of this tool. The Government's fiscal incentives could be a solution to that barrier, as it would prompt consumers to invest in energy-efficient vehicles. Moreover, policies can be implemented to regulate the age of fossil fuel vehicles being imported.

4.5.2. Identification of Barriers for Efficiency in the Transport Sector

4.5.2.1. Economic and Financial Barriers

Cost

There is a sizeable used car market in Antigua and Barbuda that provides affordable foreign-used imports, leading to a large fleet size of 54,891 vehicles, the majority of which were manufactured more than ten years ago. New vehicles are inherently more expensive than older cars as more modern technologies are incorporated into the vehicle to meet various emissions standards in the manufacturing country. The unrestricted access to a cheaper used car from other countries and relatively affordable fuel thwarts several persons from considering more expensive new cars.

Lack of policies and efficiency standards

No policy regulates the emission from vehicles entering Antigua and Barbuda. Additionally, there are no restrictions on the age of vehicles being imported into the islands. With the absence of these regulations, citizens buy vehicles ten years old and over mainly due to the low cost. Due to their age, these models of vehicles have very high emitters of CO_2. There is, however, an Environmental Levy tax for the importation of vehicles. The tax for vehicles aged 1 year and less is XCD 1000.00 and for vehicles older than one year, it is XCD 4000.00.

[43] https://www.epa.gov/greenvehicles/greenhouse-gas-emissions-typical-passenger-vehicle
[44] https://www.eia.gov/totalenergy/data/annual/showtext.php?t=pTB0208

4.5.3. Identified measures

4.5.3.1. Economic and Financial Measures

Cost

Fuel tax may have to be considered to encourage fuel saving and the purchase of more efficient vehicles such as electric buses in the transportation sector to reduce CO_2 emissions. In order to transition from ICE vehicles to electric vehicles by 2045, the country could provide tax support for those who wish to transition to electric as well as providing concessionary financing and possible options such as free charging for a period of time or a free charging solution for home solutions (which will be paid for by the increase in electricity usage to charge the vehicle). Annex O shows the GACMO modelling for EV adaptation to 2030.

Regulated Used Car Market

A possible solution for closing the price gap between ICE and EVs is the enactment of legislation to create price parity. Popular methods for disincentive used ICE vehicles importations:

1. Age restrictions- In the Caribbean, countries like Jamaica and Trinidad impose 5 years[45] and four years[46] age limits on vehicle importation.
2. Selective taxation- vehicles are taxed based on age, with more favourable taxes given to vehicles under three years old. Additional parameters used are engine size and CO_2 emissions.
3. The enforcement of emissions standard- countries like Ukraine imposed the Euro 5 standards to prevent certain used cars from being imported and favourable taxes for smaller engine volume and quantity of CO_2 missions.
4. Inspection – vehicles are screened based on standards devised by the importing country and applied in the exporting country by agents of the country. Zambia uses this approach preventing vehicles that do not meet this standard from being registered to drive on the road.[47]

4.5.3.2. Economic and Financial Measures

Feasibility Studies

These studies would investigate in detail the current policies and measures implemented in Antigua and Barbuda for the importation of vehicles on the island. It would give a thorough assessment of the GHG emissions from the transport sector. Further to this, it would then recommend revised policies and measures that Antigua and Barbuda could implement to reduce the GHG emissions in the transport sector and assist in meeting the NDC mitigation goal of a full

[45] Motor Vehicle Policy - Final Version.pdf (jamaicatradeportal.gov.jm)
[46] Used Cars Import Regulations, Duty for Trinidad And Tobago |... (japanesecartrade.com)
[47] UNEP-ITC_Background_Paper-Used_Vehicle_Global_Overview.pdf (unece.org)

fleet of Electric vehicles by 2045. This study could gauge the time of a qualified person to complete such regulation and the cost of their time. Additionally, these studies would assess the economic effects on the public and the Government of Antigua and Barbuda based on these revised implementations.

4.6. LINKAGE OF THE BARRIERS IDENTIFIED

Table 55: Linkages of Barriers by Technology in the Transport Sector

Barriers	Transport Sector			
	Solar charging stations	Improving Road infrastructure	Battery Electric Vehicles	Efficiency in the transport sector
The high investment cost for components, design, installation and operation [Capital Costs]	X	X	X	
Low demand for a specific technology [Market availability]	X		X	
Lack of legal framework & regulation	X		X	X
Limited expert on the island to install, maintain and operate. [Technical capacity]	X	X	X	
Lack of feasibility studies and available data	X	X		X

Transport sector technologies consisted of varying types of goods, including public goods (Improving Road Infrastructure), consumer goods (EVs) and non-market goods (Efficiency in Transport). These technologies face a variety of barriers to their successful implementation. There are linkages between public goods and consumer goods: road infrastructure improvements and EVs, which are limited by its capital-intensive nature. Gaining public support for these projects and locating financing hinders the opportunity for their diffusion.

Additionally, solar chargers face challenges in adoption due to the current state of the limited EV market locally. The low demand for this technology negatively impacts their prospects. A cohesive policy and regulatory framework will create an environment for the import and diffusion of EVs which therefore result in an increased uptake of solar charging stations.

Non-market goods such as efficiency in transport face key barriers related to legislation and institutional support which requires change. The political will to induce structural changes is necessary for the success of these technologies.

Lack of data and technical studies limits the diffusion and application of solar charging stations, road infrastructure improvements, and efficiency in the transport sector. Major gaps exist in current working knowledge of these technologies and their suitability for Antigua and Barbuda.
All technologies but efficiency in the transport sector face capacity barriers in the local context. Antigua and Barbuda has limited certified personnel in the repair and maintenance of the electric vehicle. Additionally, the country requires specialized personnel for the larger-scale development of solar charging station.

4.7. ENABLING FRAMEWORK FOR OVERCOMING THE BARRIERS IN TRANSPORT SECTOR TECHNOLOGIES

Table 56: Enabling Framework for the Transport Sector

Barrier	Measures	Benefits	Timeframe & Cost	AGENCY | ENTITY
High initial capital investment /cost ▪ EVs ▪ Solar Charging Station ▪ Road infrastructure	▪ Bulk buying of components for solar charging stations ▪ Assessing concessional finance mechanism for the road infrastructure. ▪ Government fleet transition to EV to stimulate the local EV market. ▪ Government installs solar charging station for its electric vehicle fleet	▪ Reduced greenhouse gas emission from the transport sector. ▪ Reduce the amount of oil importation into the country Higher adoption of EVs ▪ Bulk buying reduces the initial cost of the technologies solar	▪ EV 2035 - USD 55 Million ▪ Solar charging station 2035 - USD 3.5 Million- Solar ▪ Road infrastructure 2030 - USD 19.9 Million	- Customs and Excise Division - Car dealerships - Ministry of Works and Housing (MoWH) - Ministry of Finance & Corporate Governance - Antigua and Barbuda Transport Board - Ministry of Public Utility, Civil Aviation and Energy
Legal framework & regulation ▪ EVs ▪ efficiency in transport ▪ Solar charging station	▪ Develop a complementary policy for the regulation of the used car market for electric vehicles. ▪ Create standards and regulation on the age and emission of vehicles imported into Antigua. ▪ Enactment of legislation to create price parity using methods such as age restriction for ICE vehicles. ▪ Enforcement of vehicles emission standards upon registration of a vehicle	▪ Higher importation of EVs hence increased need for solar charging stations ▪ Reduced greenhouse gas emission from the transport sector	Efficient transport 6 years USD 1, 22, 750 EV 9 years Solar charging station 9 years	- Government of Antigua and Barbuda - Customs and Excise - Transport Board - Car dealerships (new and used)

Barrier	Measures	Benefits	Timeframe & Cost	AGENCY | ENTITY
Low demand ▪ EVs ▪ Solar Charging Stations	▪ Banning the importation of ICE vehicles ▪ Increase local accessibility to used EVs.	▪ Increased uptake of electric vehicles ▪ Development of related markets (public and private) to support new technologies	▪ 2030	- Car Dealerships (new and used) - Department of the Environment - Customs and Excise - Transport Board
Feasibility Studies ▪ Solar Charging Stations ▪ Road infrastructure ▪ Efficiency in Transport	▪ Feasibility studies are required for solar charging stations to determine suitability and functionality. ▪ Road infrastructure feasibility studies are needed for the target development to decide the best interventions to deal with unique hazards ▪ Transport sector efficiency needs studies on the implications of policy changes for the used car market and potential consumers	▪ A better understanding of the solar charging system technology for buildings ▪ Best fit improvements for road infrastructure improvements to provide maximum resilience. ▪ Most effective policy implementation that will simultaneously reduce emissions without negatively impacting the needs of vehicle owners and sales operations	▪ Solar Charging Stations 1 year- $100,000 ▪ Road infrastructure 1 years- $200,000 ▪ Efficiency in Transport ▪ $182, 500	- Customs and Excise Division - Ministry of Energy - APUA - Transport Board - Car Dealerships (new and used) - Department of the Environment - Ministry of Works and Housing - West Indies Oil Company
Limited Expertise ▪ Solar Charging Stations ▪ EVs	▪ Development of training programs for current technicians, electricians and mechanics for EVs ▪ Technical and Educational Vocational Training (TVET) for young persons establishing a	▪ Job creation for technical specialists at various levels of the value chain ▪ Economic diversification in new industries	▪ Solar charging station and BEV 5 years cost USD500,000	- Customs and Excise Division - Ministry of Energy - Department of the Environment

Barrier	Measures	Benefits	Timeframe & Cost	AGENCY | ENTITY
	career in technical fields for solar charging station ▪ Increase local retailers for EVs ▪ Increase training for health and safety personnel and first responders for EVs incidents /accidents ▪ Create scholarship Programs for young persons ▪ Development of train the trainer (TTT) courses to upskill trainers for solar charging station and EV			- Antigua Public Utilities Authority (APUA), - Ministry of Education - National Training Agency: partners to be selected from 1. Antigua State College (ASC); 2. A&B International Institute of Technology (AIIT); 3. A&B Institute of Continuing Education (ABICE);

5. SUMMARY AND CONCLUSIONS

5.1. SUMMARY OF PROCESS OUTCOMES

The Barrier Analysis and Enabling Framework step was the completion of the TNA that followed the guidelines outlined in the TNA Handbook 'Overcoming Barriers to the Transfer and Diffusion of Climate Technologies'. A diverse group of stakeholders, from public and private sector agencies, contributed through participation in one-to-one consultations, a technology working group session and a field visit. This flexible range of options for engagement maximized stakeholder feedback and eliminated the constraints of assembling the TWGs on multiple occasions to effectively complete the process.

The Department of the Environment notes that the methodology outlined in the TNA handbook has the potential to produce results which are biased by the uninformed perception of some stakeholders. The results of the process were skewed based on the composition of stakeholders who were willing to participate. In order to adjust for this, the expert judgement of the Department of Environment was also considered resulting in a variation in the technologies presented in this report when compared to the initial TNA report. This resulted in a shortened list for the Buildings Sector and longer list for the Water sector which was more reflective of the national goals.

The combined critical barriers for the water, transport and building sector broadly included the following sub-categories: financial, market conditions, institutional and organizational capacity, socio-cultural / behavioural and education and awareness. The availability of and access to financial resources was a dominant barrier in each of the five technologies. Based on the recent Covid 19 pandemic as well as the increased frequency of hurricanes and the related impact on the economy this barrier is set to be with the country for a long time. Expanding market opportunities and regulations were deemed vital in promoting the transfer of any technology that can promote climate resilience; while addressing institutional capacity and organizational structure within public and private sectors would aid in the diffusion of publicly provided goods. Increased education and awareness were acknowledged as another cross-cutting measure that would benefit the wide-scale diffusion of all technologies.

5.2. CONCLUSIONS AND RECOMMENDATIONS

Successful technology transfer in Antigua and Barbuda will require a combination of activities, processes and agencies focused on building capacity and resilience to climate change. Social, economic, and environmental indicators must be carefully selected, clearly stated, measurable and consistent with national development objectives and climate change goals.

In view of the recommendations from Step 1 – outlined in the TNA Report – the BAEF step sought to:

- promote private sector interest and ownership of market-based technologies – this was achieved through close collaboration with the Antigua and Barbuda Chamber of Commerce and introducing the process to local retailers; and
- engage community influencers to support knowledge transfer and on-ground activities, accomplished by promoting the further development of the TNA project to include technologies that are important to community-based NGOs, the Community Development Division within the Ministry of Social Transformation, and the Barbuda Council.

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ANNEX A: TNA CONSULTATION ATTENDANCE

One-to-One Consultations: Jan-24, 2020 to Feb-7, 2020

	NAME	DESIGNATION	ORGANIZATION
1.	McClure Simon	Engineer	APUA – Water Division
2.	Hastin Barnes	Engineer	APUA – Water Division
3.	Lyndon Prosper	Plant Superintendent	APUA – Water Division. (Barbuda)
4.	Ogden Kelly Burton	Park Manager	National Parks (Barbuda)
5.	Ruleta Camacho-Thomas	Adviser	National Parks
6.	Sharon Dalso	Community Outreach	Community Development Division
7.	Brenda Thomas-Odlum	Community Outreach	Community Development Division | Freetown Community Gp.
8.	Andel Trotman	Community Outreach	Community Development Division
9.	Martin Cave	Executive Director	Antigua/Barbuda Chamber of Commerce
10.	Gem Reynolds	Officer	Bureau of Standards
11.	Timothy Payne	Director	Barnes Hill Community Development Organization
12.	Alex Spencer	Solar Expert	CariSun Renewable Energy
13.		Sales Representative	Northcoast Hardware
14.		Sales Representative	Antigua Plumbing
15.		Sales Representative	Townhouse Furnishings
16.		Retail Store Assistant	Caribbean Water Treatment

Stakeholder Briefing Meeting: Feb-11, 2020

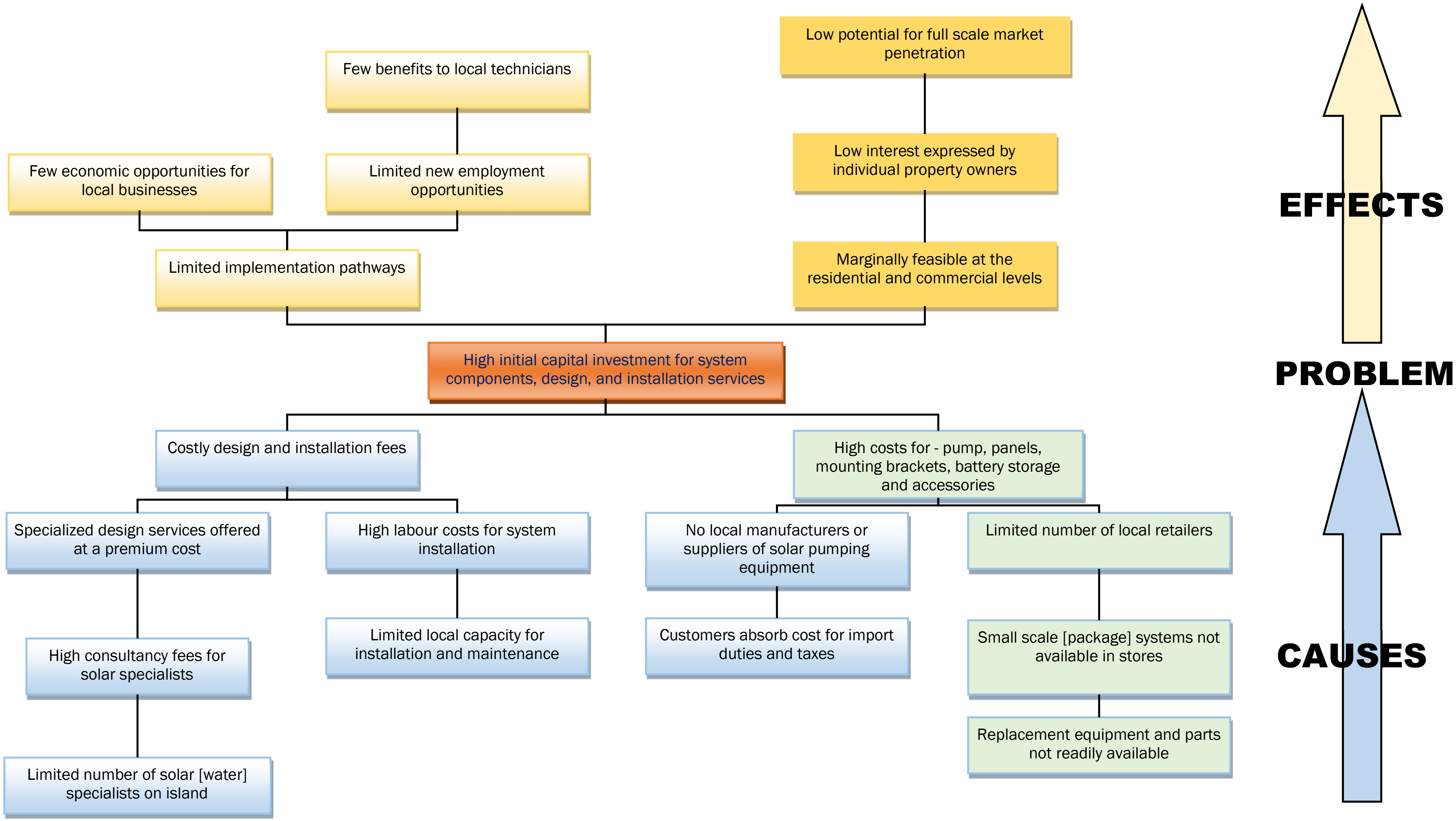
	NAME	DESIGNATION	ORGANIZATION
1.	Camaria Holder	TNA Consultant	
2.	Jamila Gregory	TNA Coordinator	Dept. of the Environment
3.	Amira McDonald	Project Assistant	Dept. of the Environment
4.	William Keith Thomas	TNA Consultant	KTEC
5.	Rashauna Adams-Matthews	Consultant	Dept. of the Environment
6.	Hastin Barnes	Engineer	APUA – Water Division
7.	Martin Cave	Executive Director	Antigua/Barbuda Chamber of Commerce
8.	Kelly Hedges	Consultant	Dept. of the Environment
9	Rashauna Adams-Matthew	Environment Social Safeguard Officer	Dept. of the Environment
10.	Ato Lewis	Senior Environment Officer	Dept. of the Environment
11.	Sharon Dalso	Community Officer	Community Development Division
12.	D'Kaboo Brann	Community Outreach	Dept. of the Environment

Barbuda Council Consultation: Feb-19, 2020

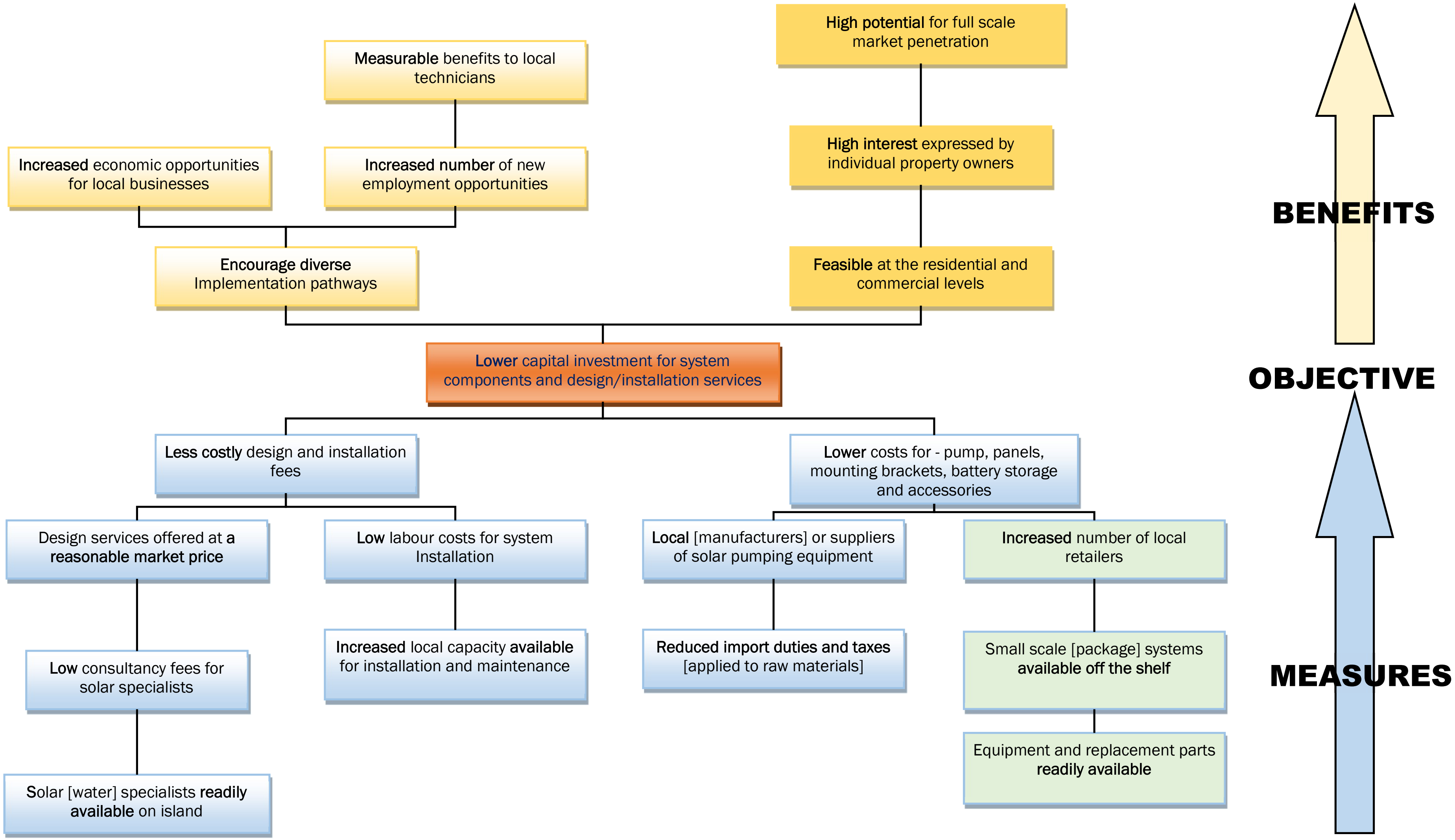
No.	NAME	DESIGNATION
1.	Sharima Myers	Council Member
2.	Hon. Trevor Walker	M.P/Barbuda
3.	Mackeisha Desouza	Barbuda Council
4.	Devon Warner	Barbuda Council
5.	Keith Thomas	KTEC TNA Consultant
6.	Kendra Beazer	Barbuda Council
7.	Wayde Burton	Barbuda Council
8.	Camaria Holder	TNA Consultant
9.	Jamila Gregory	TNA Project Coordinator (DOE)
10.	Avelyn Thomas	Rec. Secretary
11.	Amira McDonald	Project Assistant (DOE)
12.	Gita Gardner	Report Writer (DOE)
13.	Calsey Joseph	Barbuda Council

ANNEX B: LOGICAL PROBLEM AND OBJECTIVE TREES FOR SOLAR PUMPING SYSTEMS

PROBLEM TREE - HIGH INITIAL CAPITAL INVESTMENT FOR SYSTEM COMPONENTS, DESIGN AND INSTALLATION SERVICES & LIMITED ESTABLISHED RETAILERS AND PACKAGE SYSTEMS AVAILABLE ON ISLAND

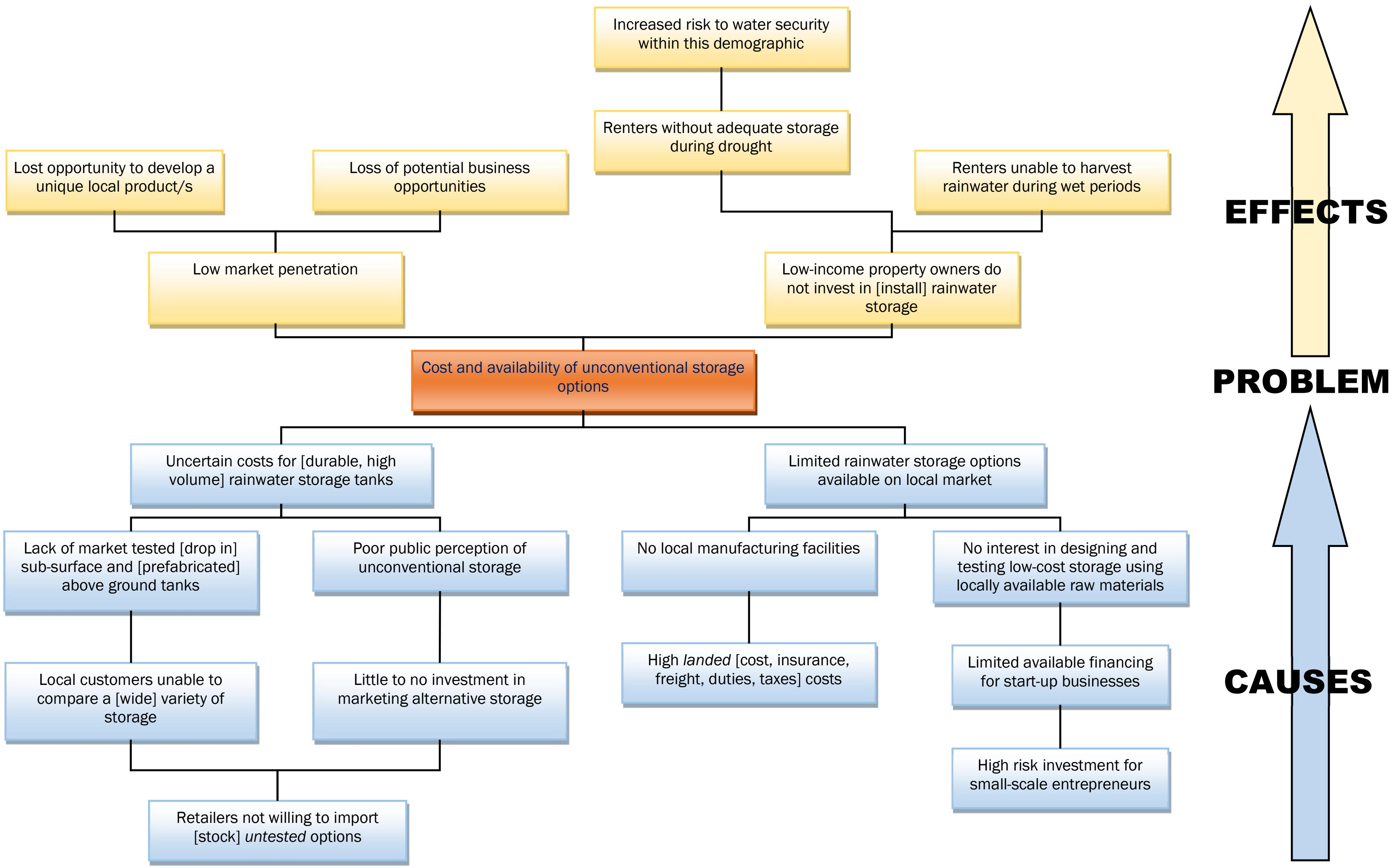


OBJECTIVE TREE – LOWER CAPITAL INVESTMENT FOR SYSTEM COMPONENTS AND DESIGN/INSTALLATION SERVICES

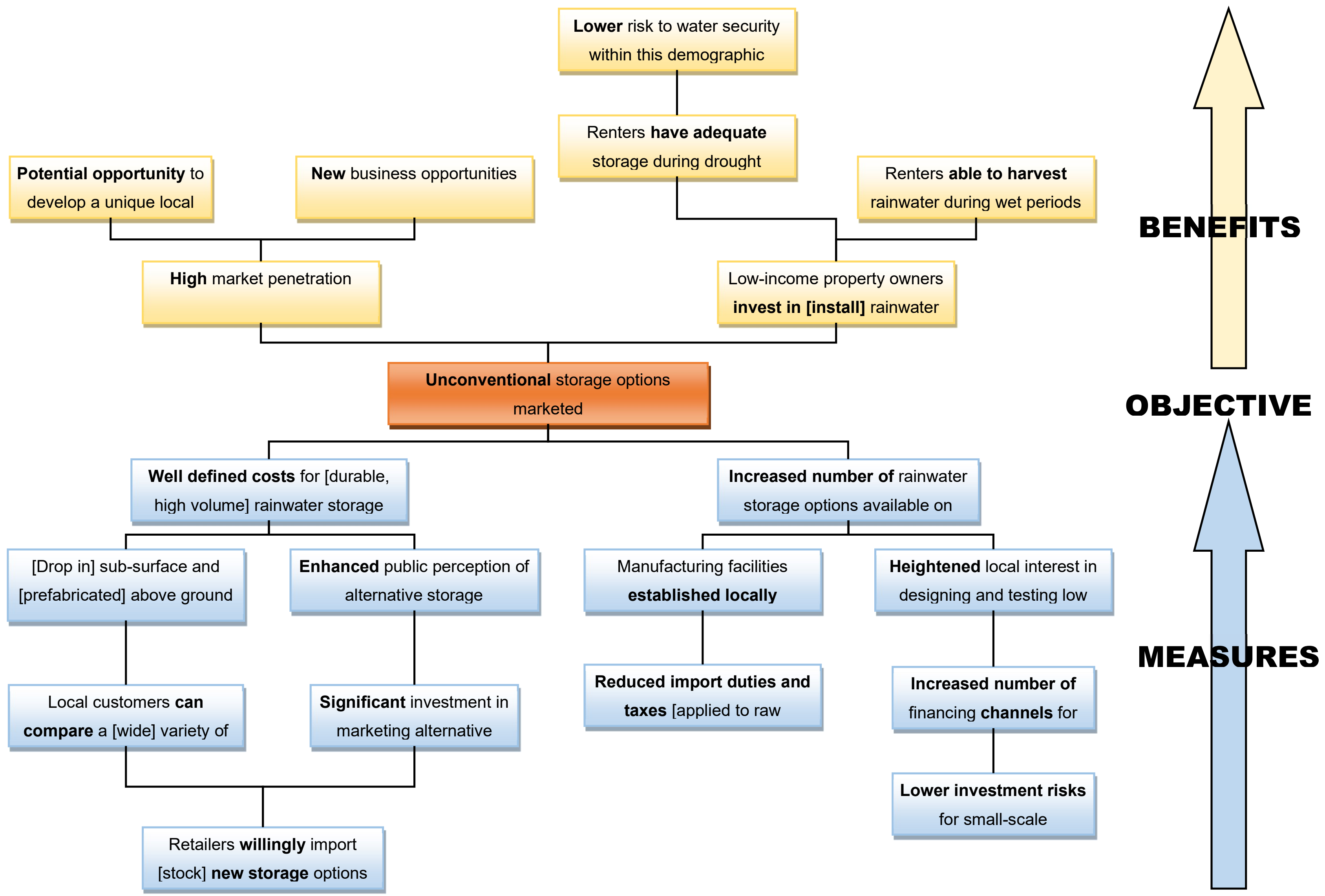


ANNEX C: LOGICAL PROBLEM AND OBJECTIVE TREES FOR RAINWATER HARVESTING

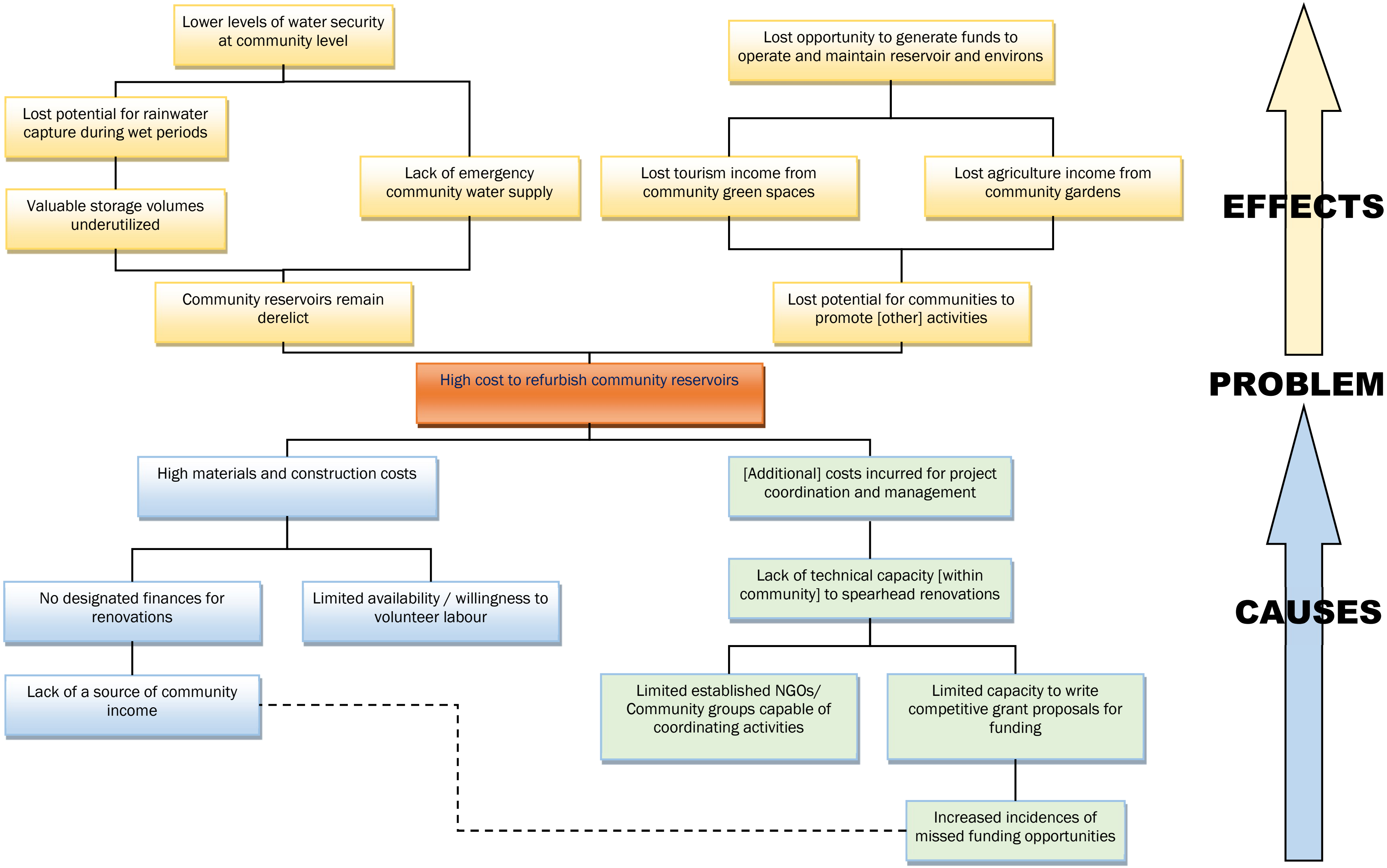
PROBLEM TREE - COST AND AVAILABILITY OF UNCONVENTIONAL RAINWATER STORAGE OPTIONS



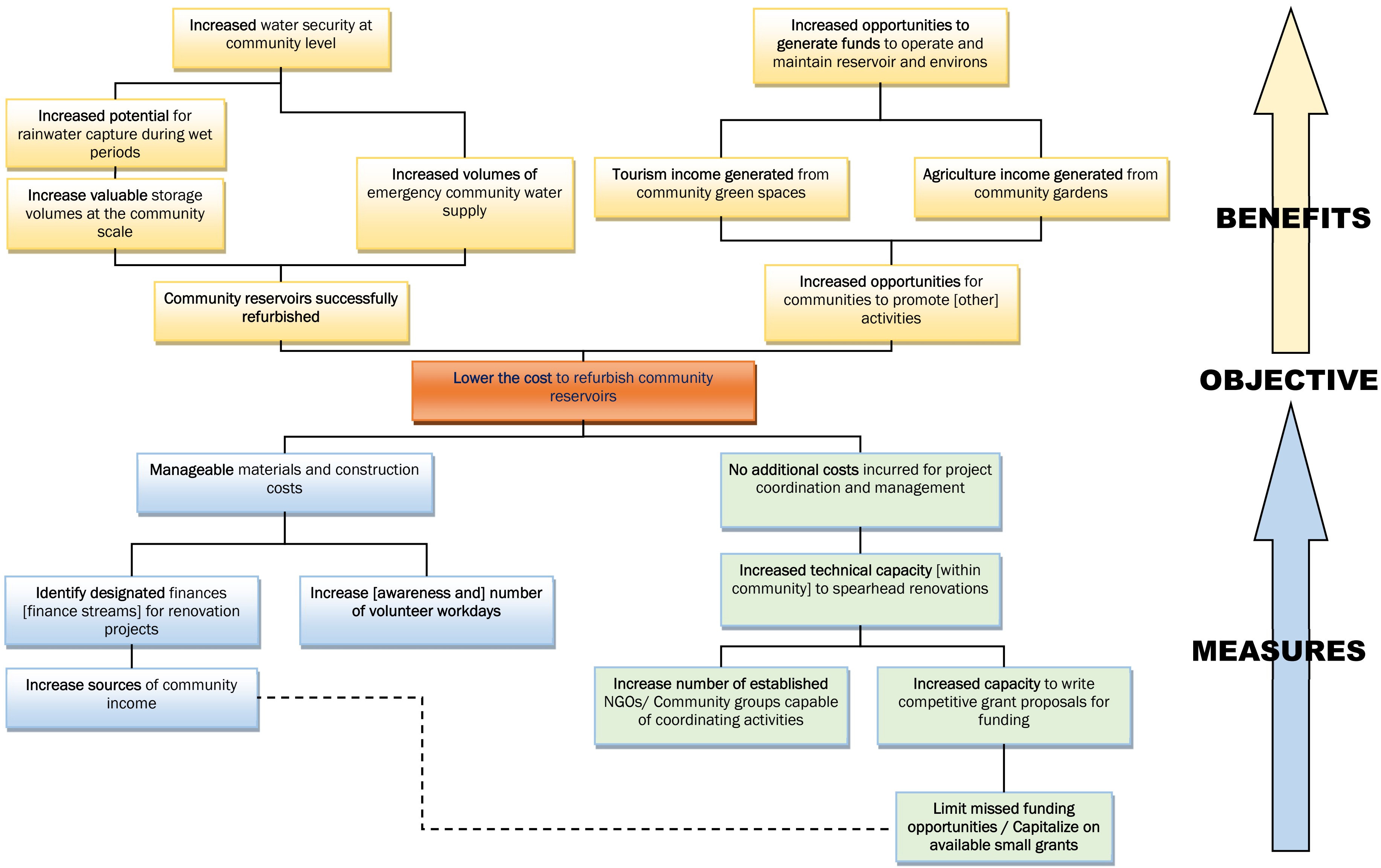
OBJECTIVE TREE – UNCONVENTIONAL STORAGE OPTIONS WIDELY MARKETED



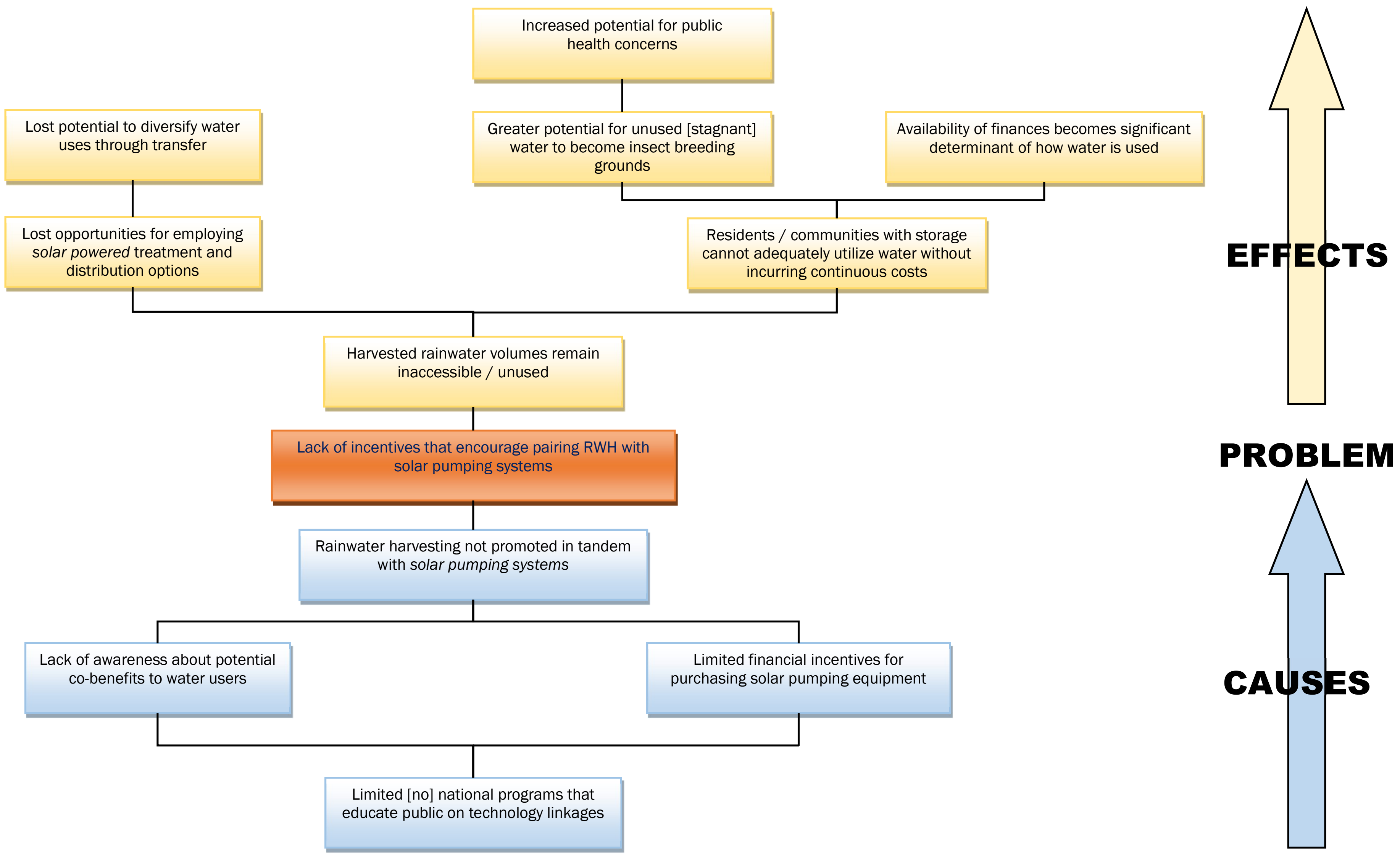
PROBLEM TREE – HIGH COSTS TO REFURBISH COMMUNITY RESERVOIRS OR INSTALL COMMUNITY TANKS AND CATCHMENTS



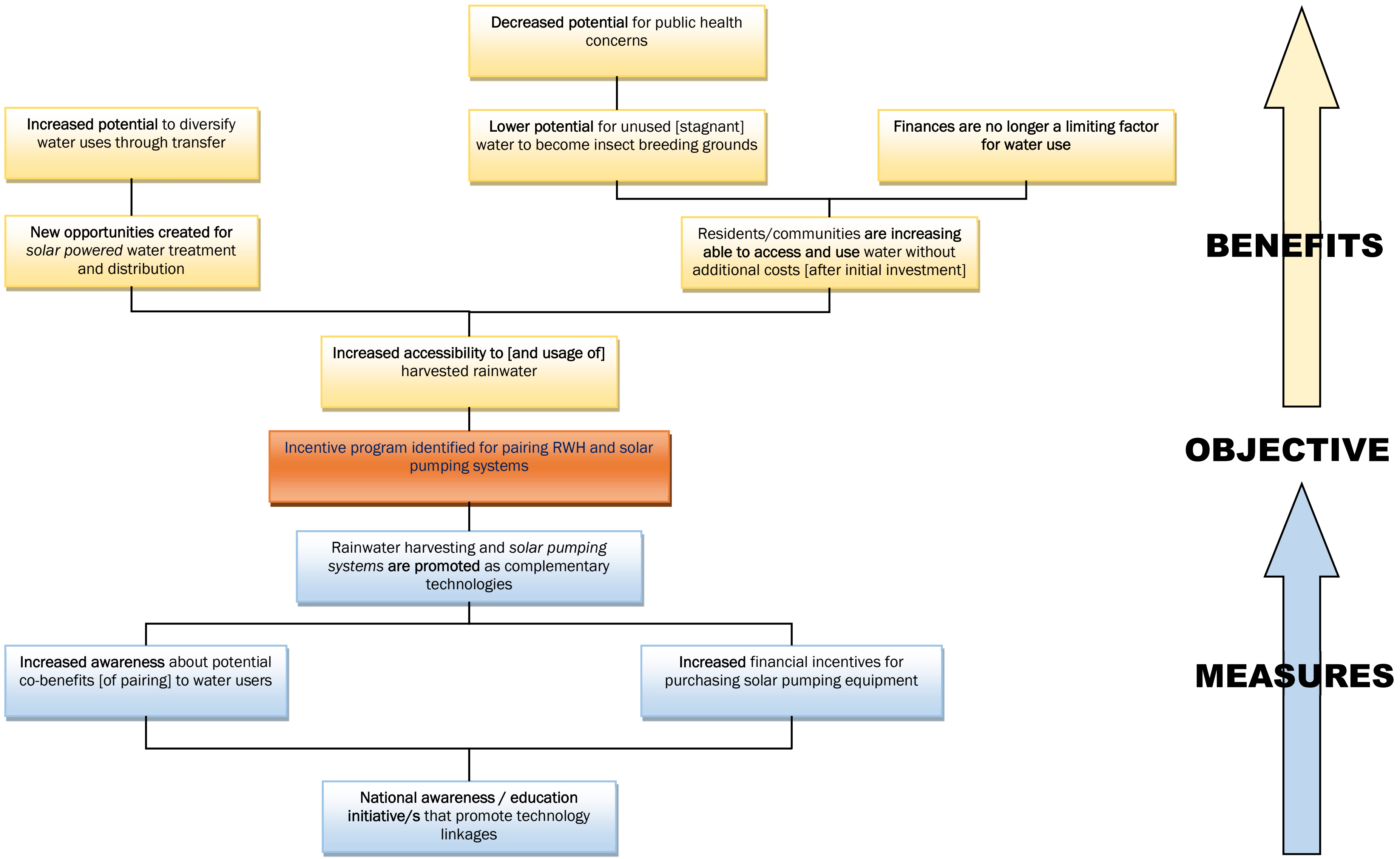
OBJECTIVE TREE – LOWER THE COST TO REFURBISH AND MAINTAIN COMMUNITY RESERVOIR



PROBLEM TREE - LACK OF INCENTIVES TO ENCOURAGE PAIRING RAINWATER HARVESTING WITH SOLAR PUMPING SYSTEMS

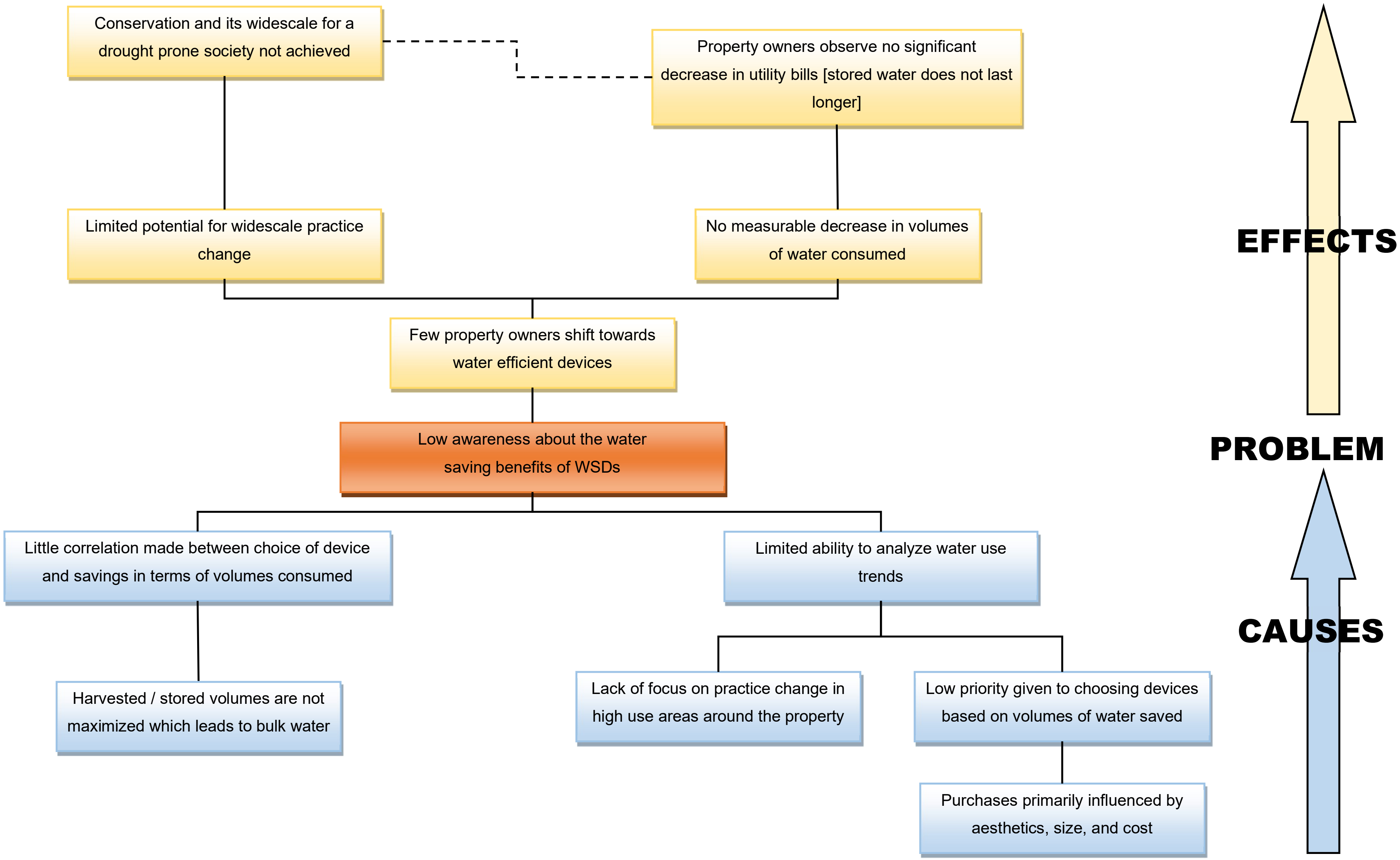


OBJECTIVE TREE – INCENTIVE PROGRAMS IDENTIFIED FOR PAIRING RWF AND SOLAR PUMPING SYSTEMS

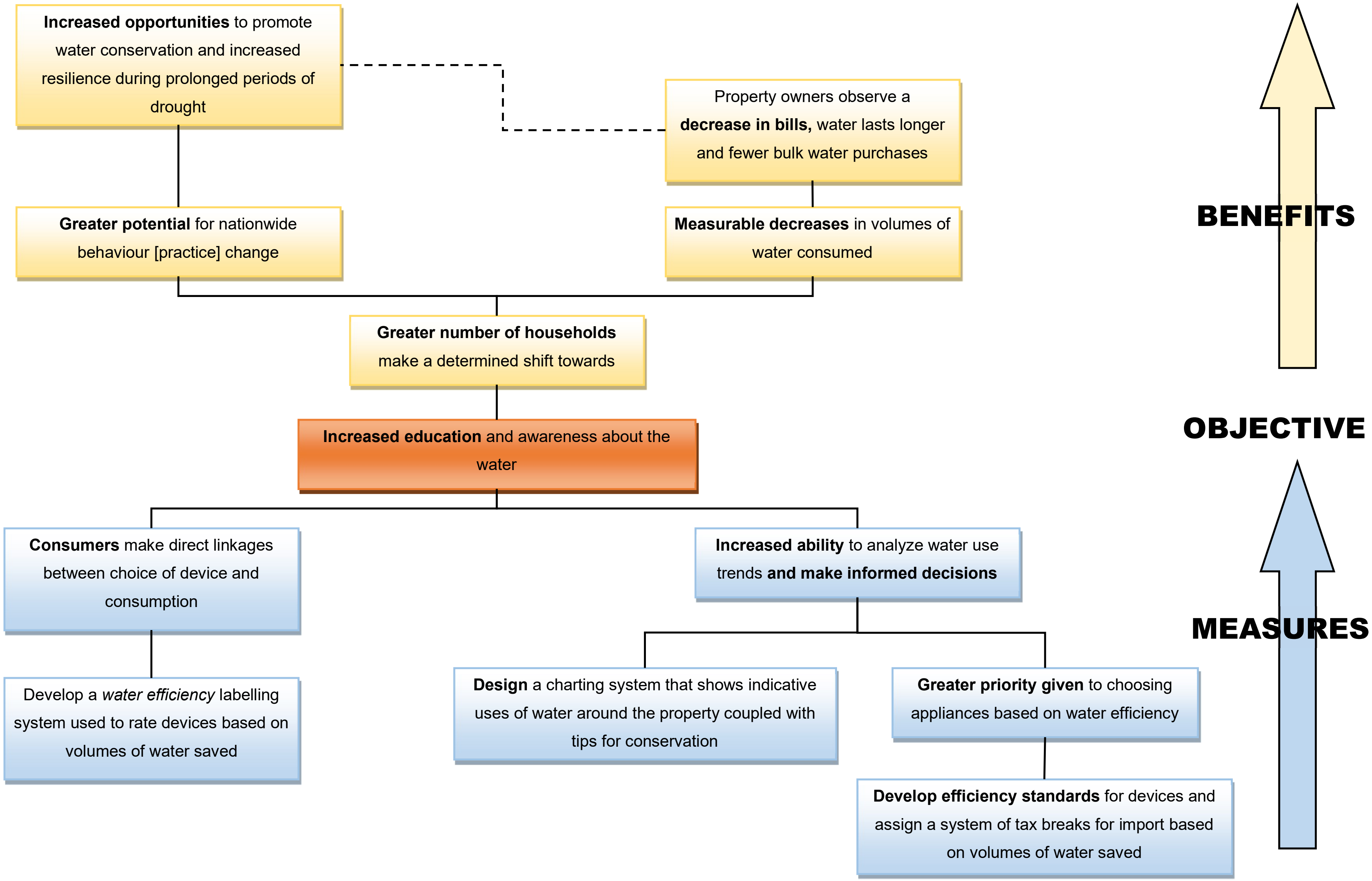


ANNEX D: LOGICAL PROBLEM AND OBJECTIVE TREES FOR WATER-SAVING DEVICES

PROBLEM TREE – LOW AWARENESS ABOUT THE WATER-SAVING BENEFITS OF HOUSEHOLD APPLIANCES AND DEVICES

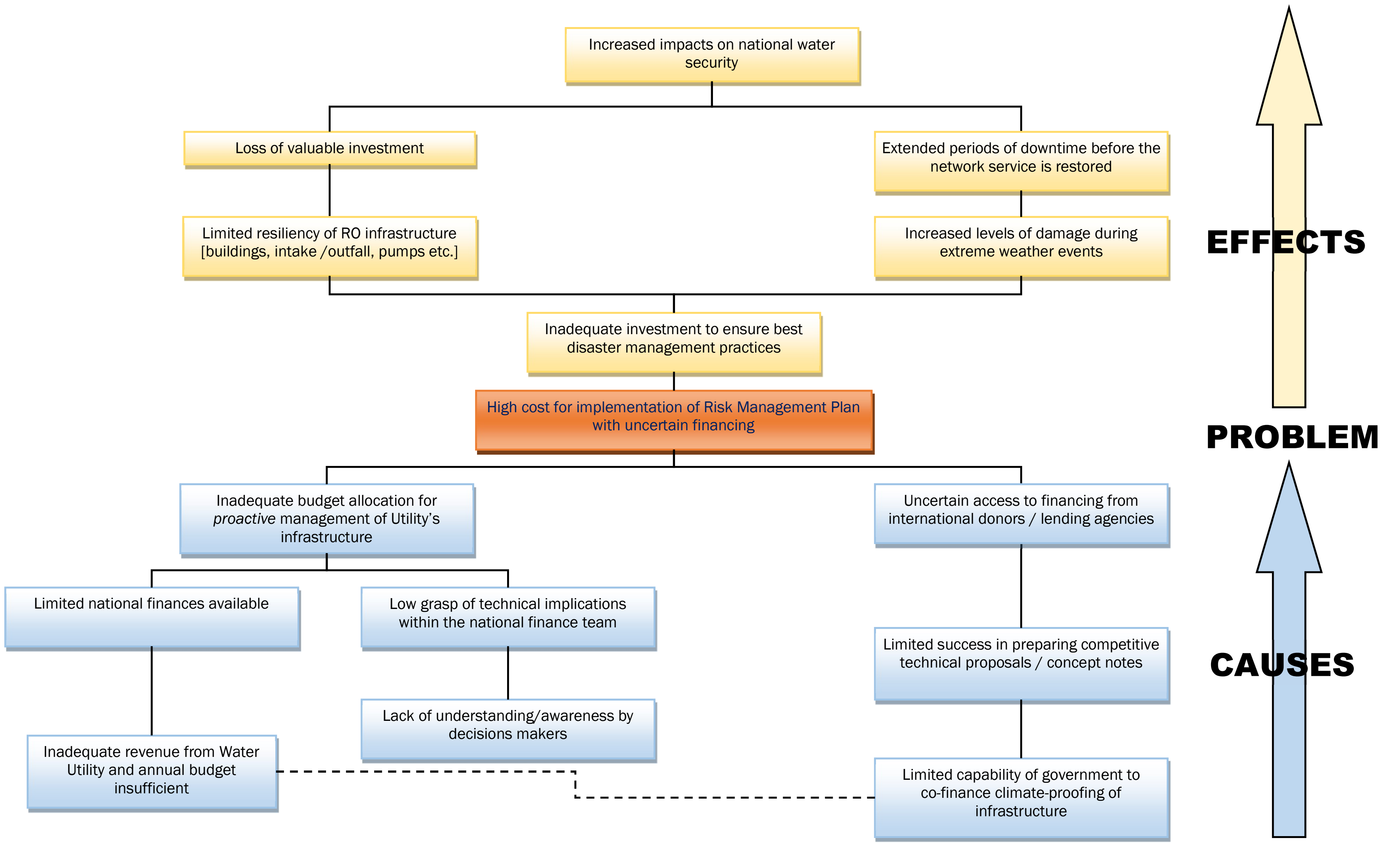


OBJECTIVE TREE – INCREASED EDUCATION AND AWARENESS ABOUT THE WATER SAVING BENEFITS OF WSD

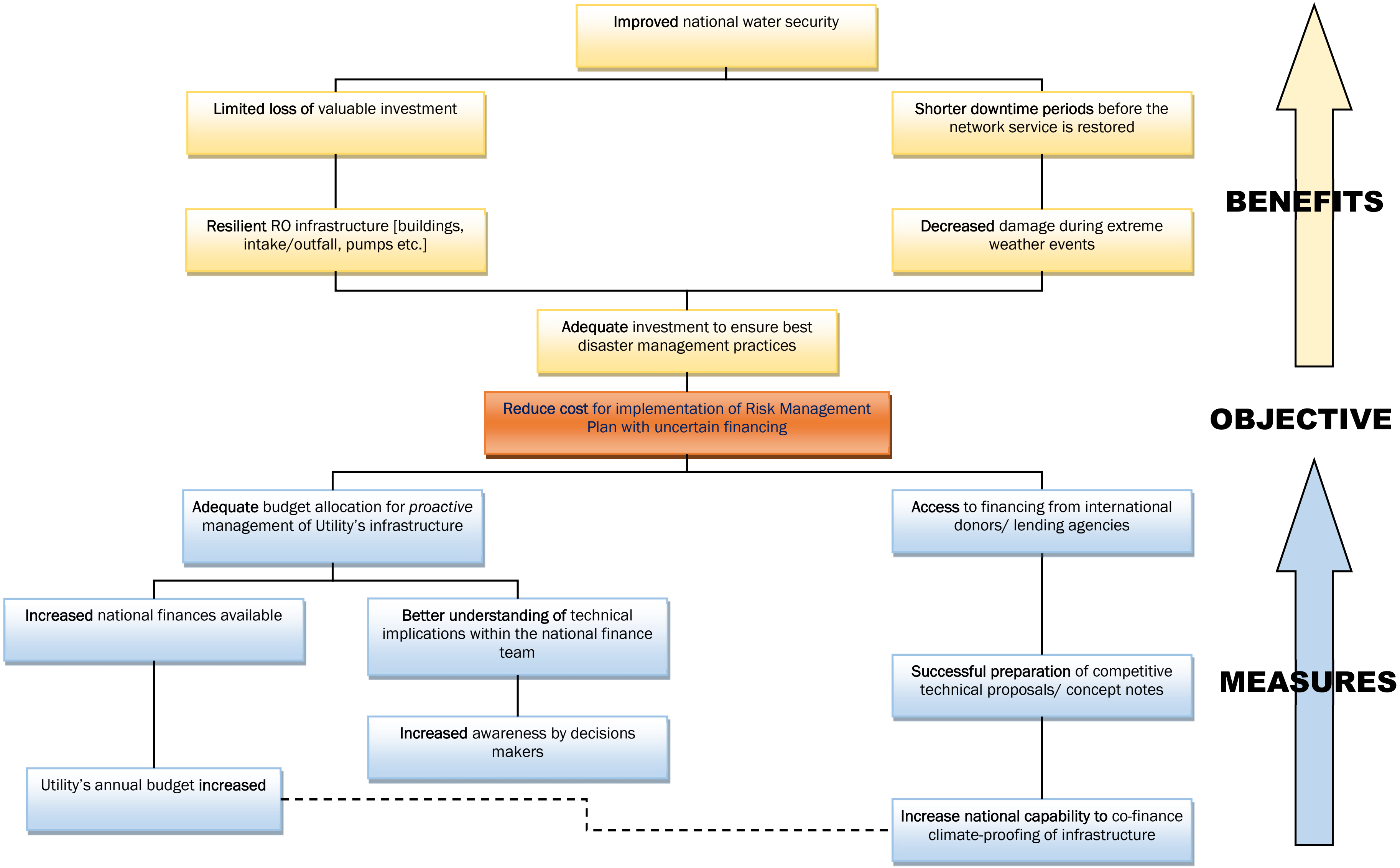


ANNEX E: LOGICAL PROBLEM AND OBJECTIVE TREES FOR CLIMATE-PROOFING ASSETS

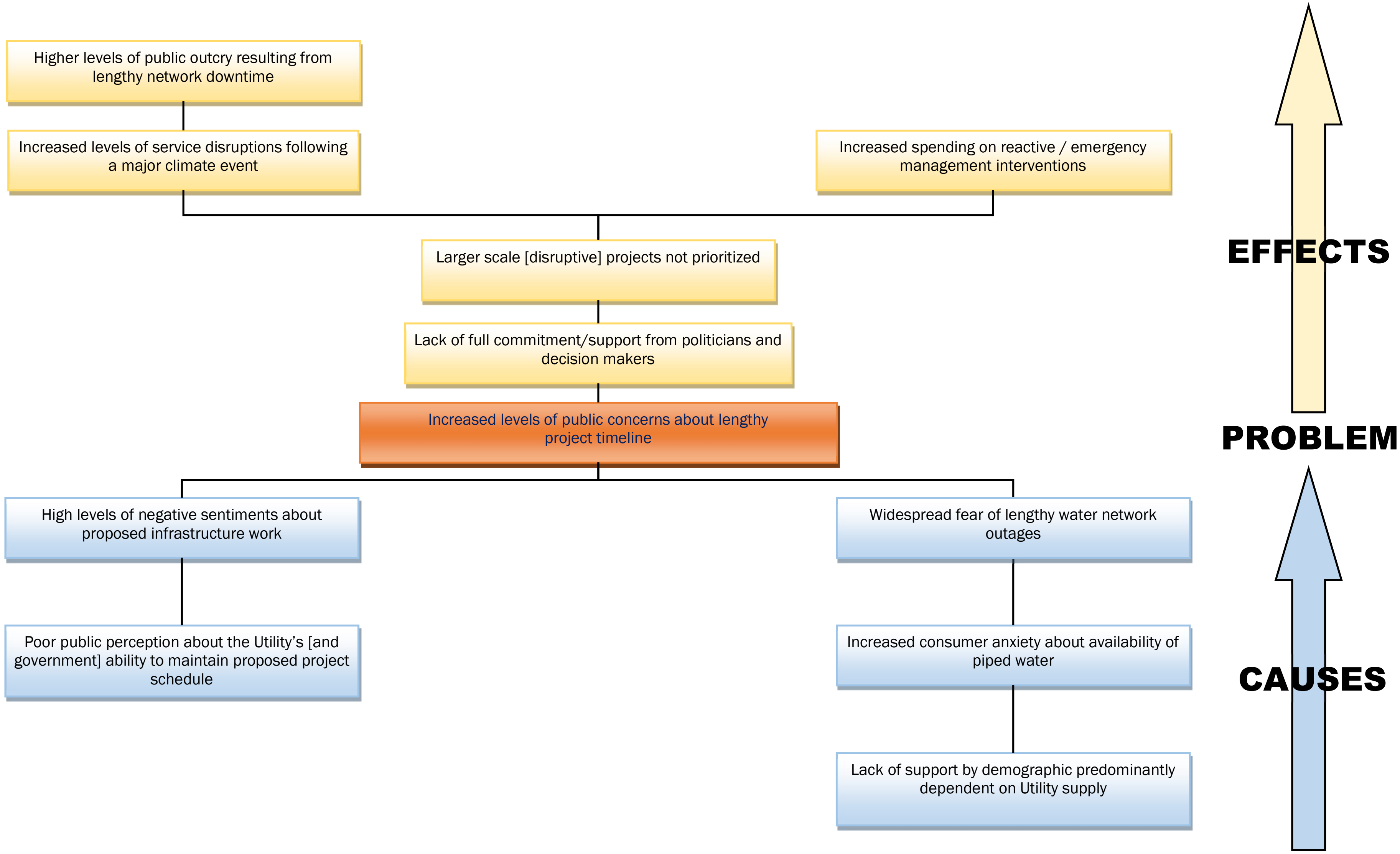
PROBLEM TREE – HIGH COSTS FOR IMPLEMENTATION OF RISK MANAGEMENT PLAN WITH UNCERTAIN FINANCING



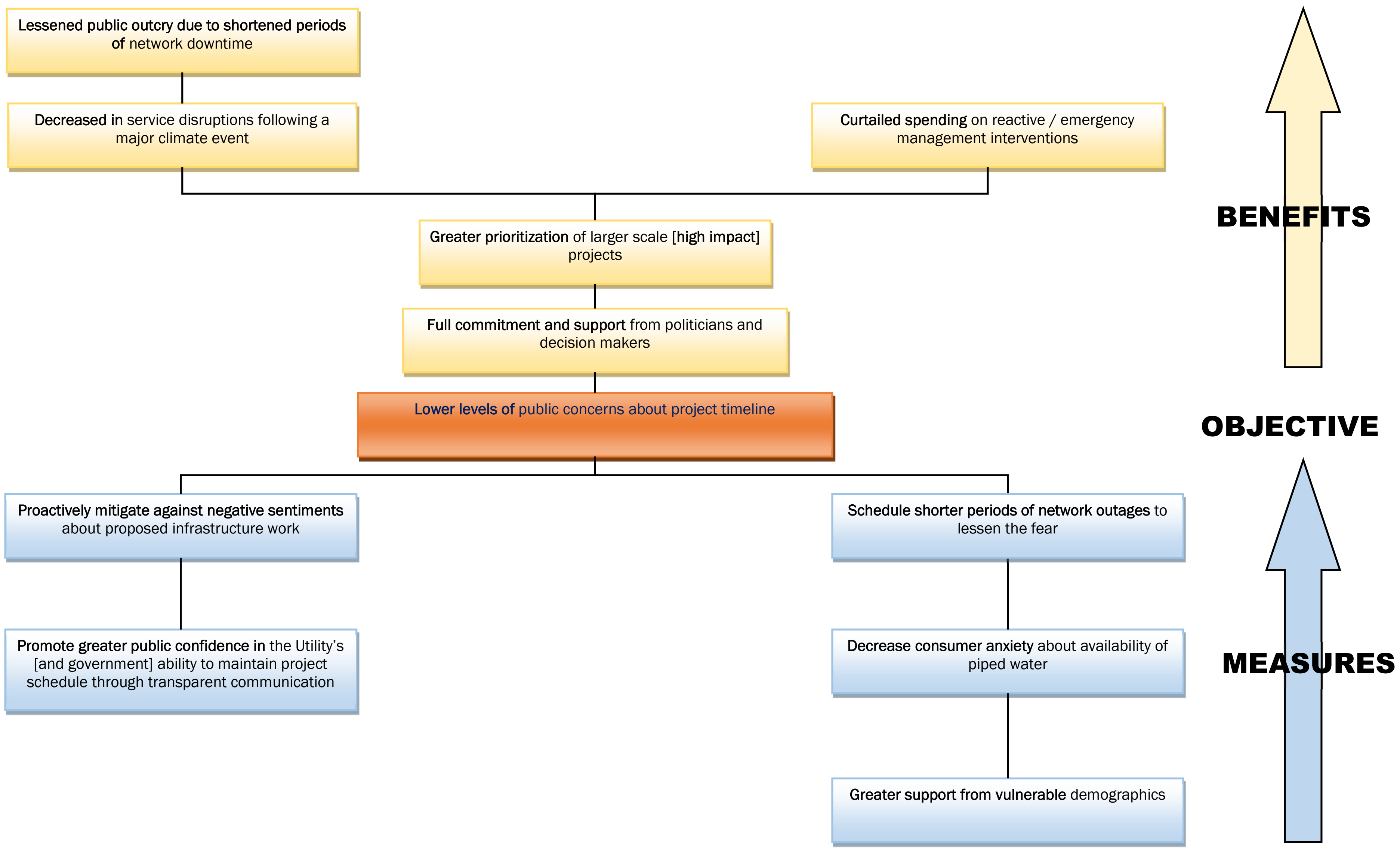
OBJECTIVE TREE – REDUCE COST FOR IMPLEMENTATION RISK MANAGEMENT PLAN BY IDENTIFYING FINANCING STREAMS



PROBLEM TREE - INCREASED LEVELS OF PUBLIC CONCERNS ABOUT LENGTHY PROJECT TIMELINE

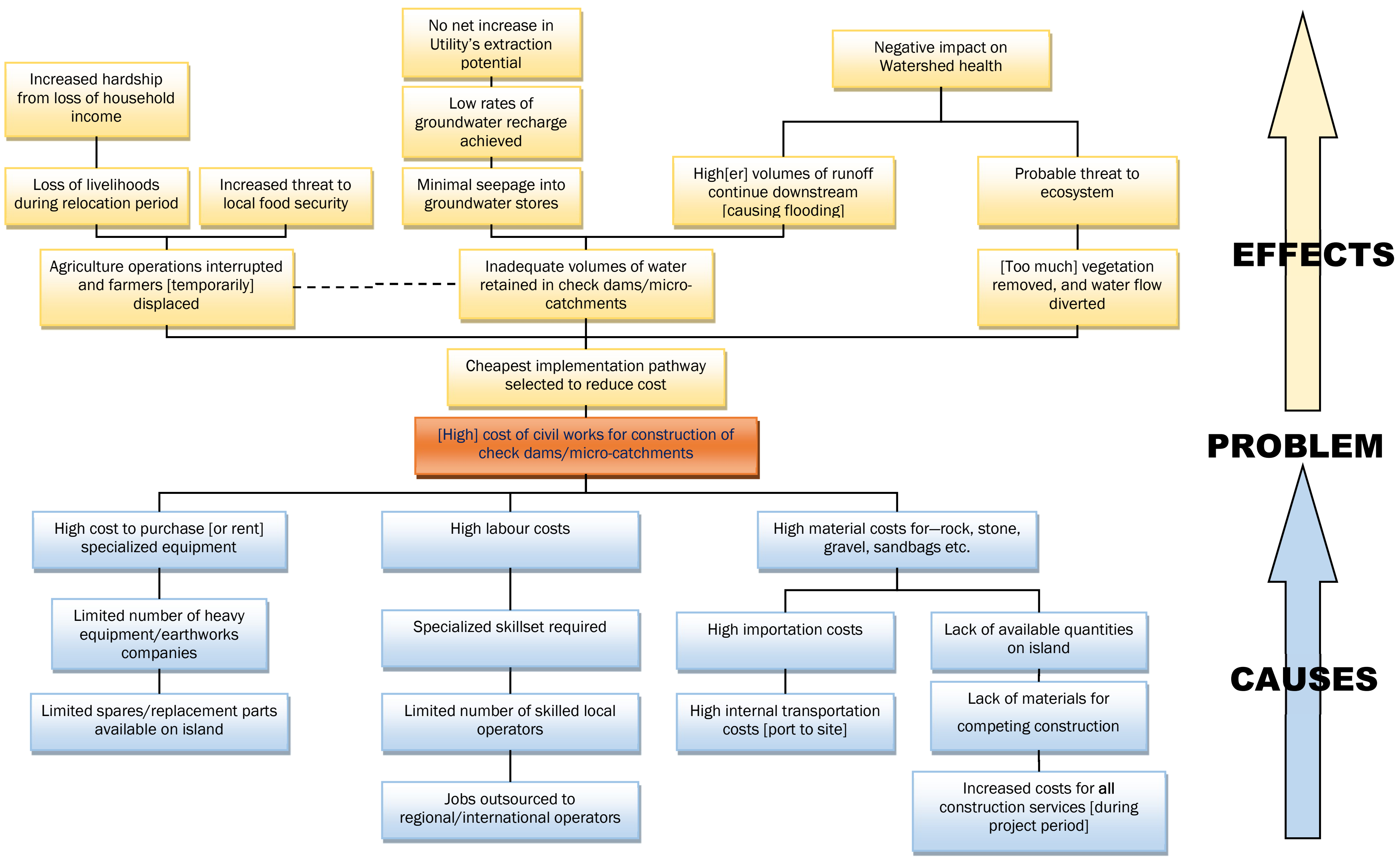


OBJECTIVE TREE – ADDRESS PUBLIC CONCERNS ABOUT LENGTH PROJECT TIMELINES

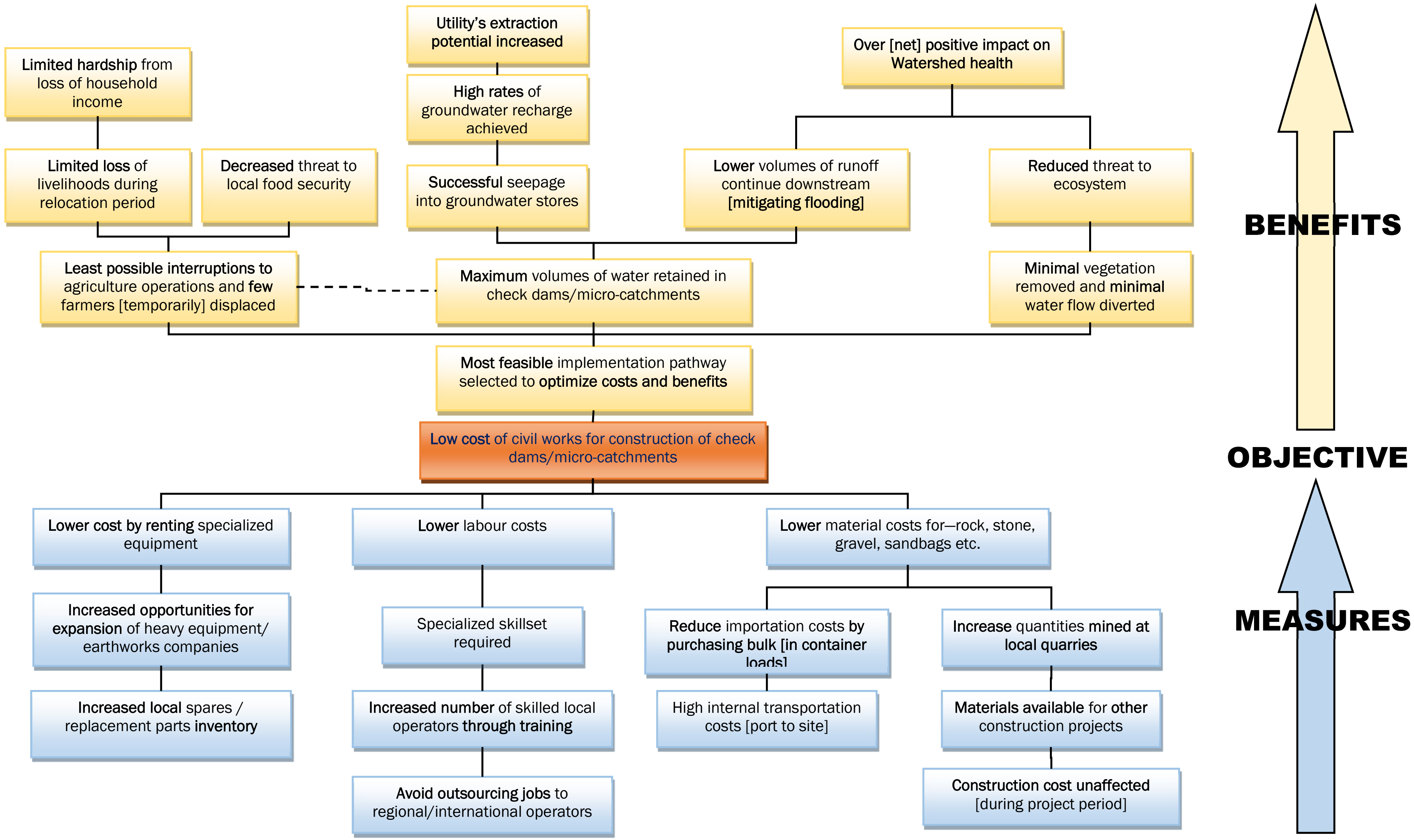


ANNEX F: LOGICAL PROBLEM AND OBJECTIVE TREES FOR STORMWATER RECLAMATION AND REUSE

PROBLEM TREE - HIGH COSTS OF CIVIL WORKS FOR CONSTRUCTION OF CHECK DAMS / MICRO-CATCHMENTS

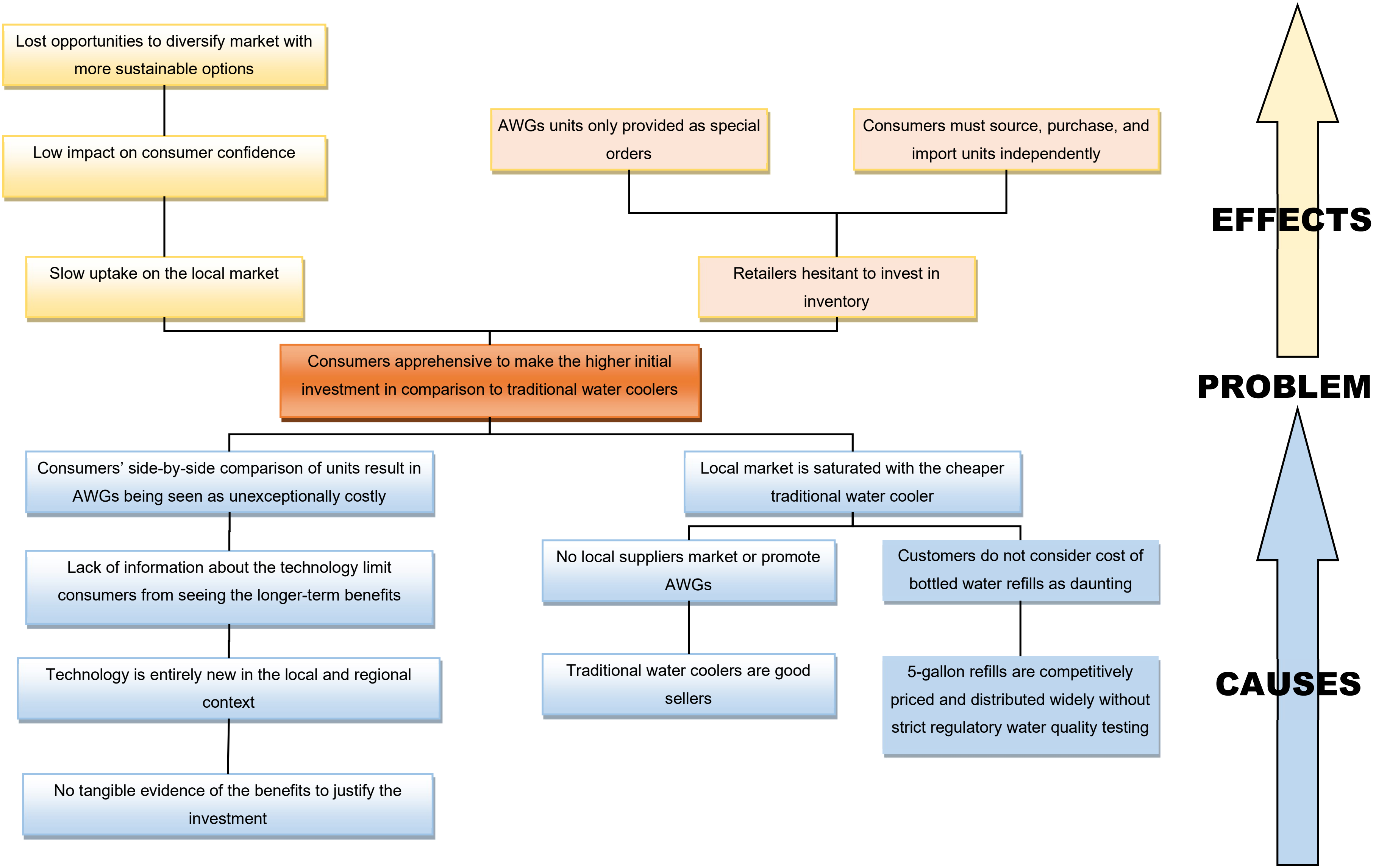


OBJECTIVE TREE – DECREASED COST OF CIVIL WORKS FOR CONSTRUCTION OF CHECK DAMS / MICRO-CATCHMENTS

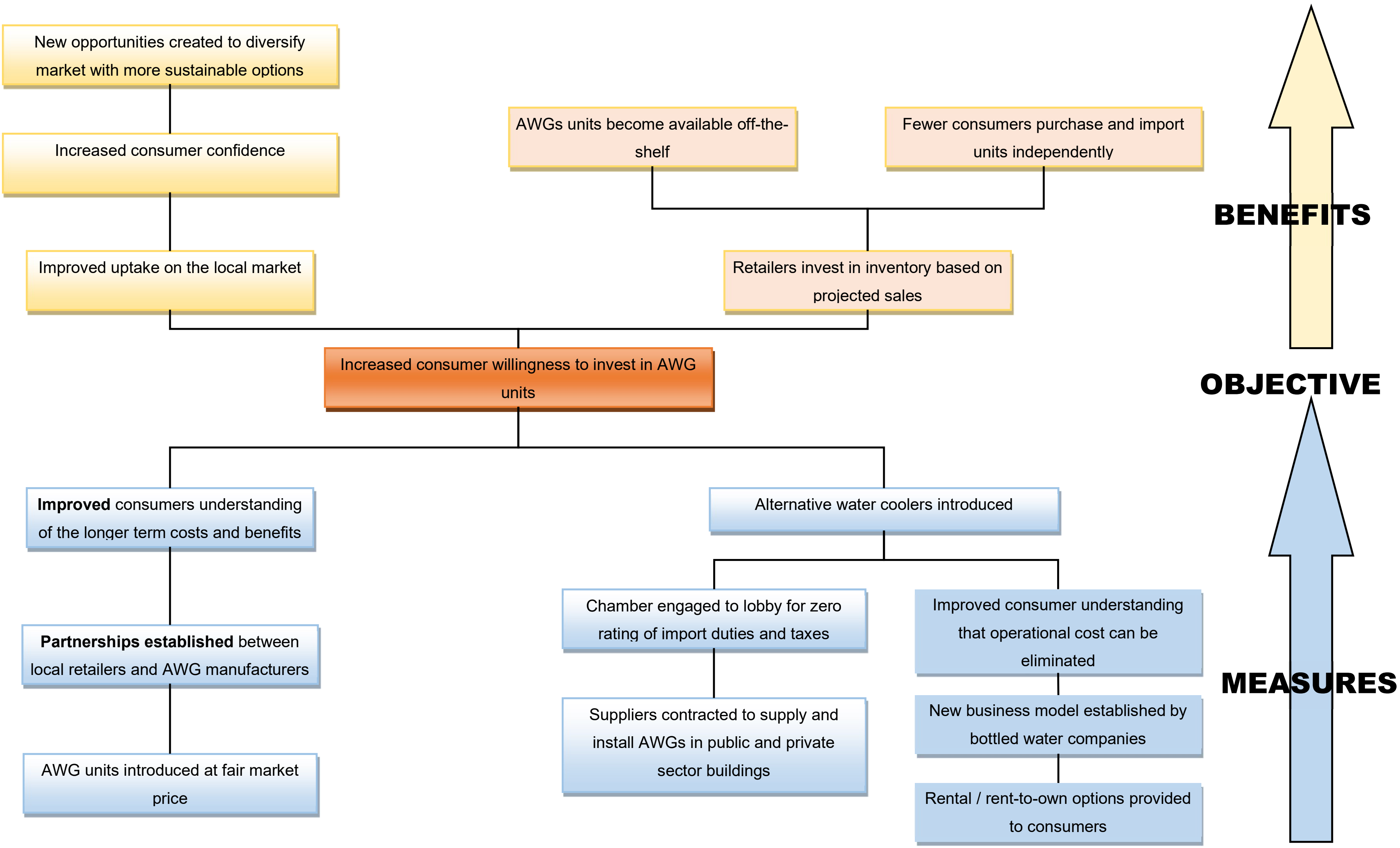


ANNEX G: LOGICAL PROBLEM AND OBJECTIVE TREES FOR ATMOSPHERIC WATER GENERATORS

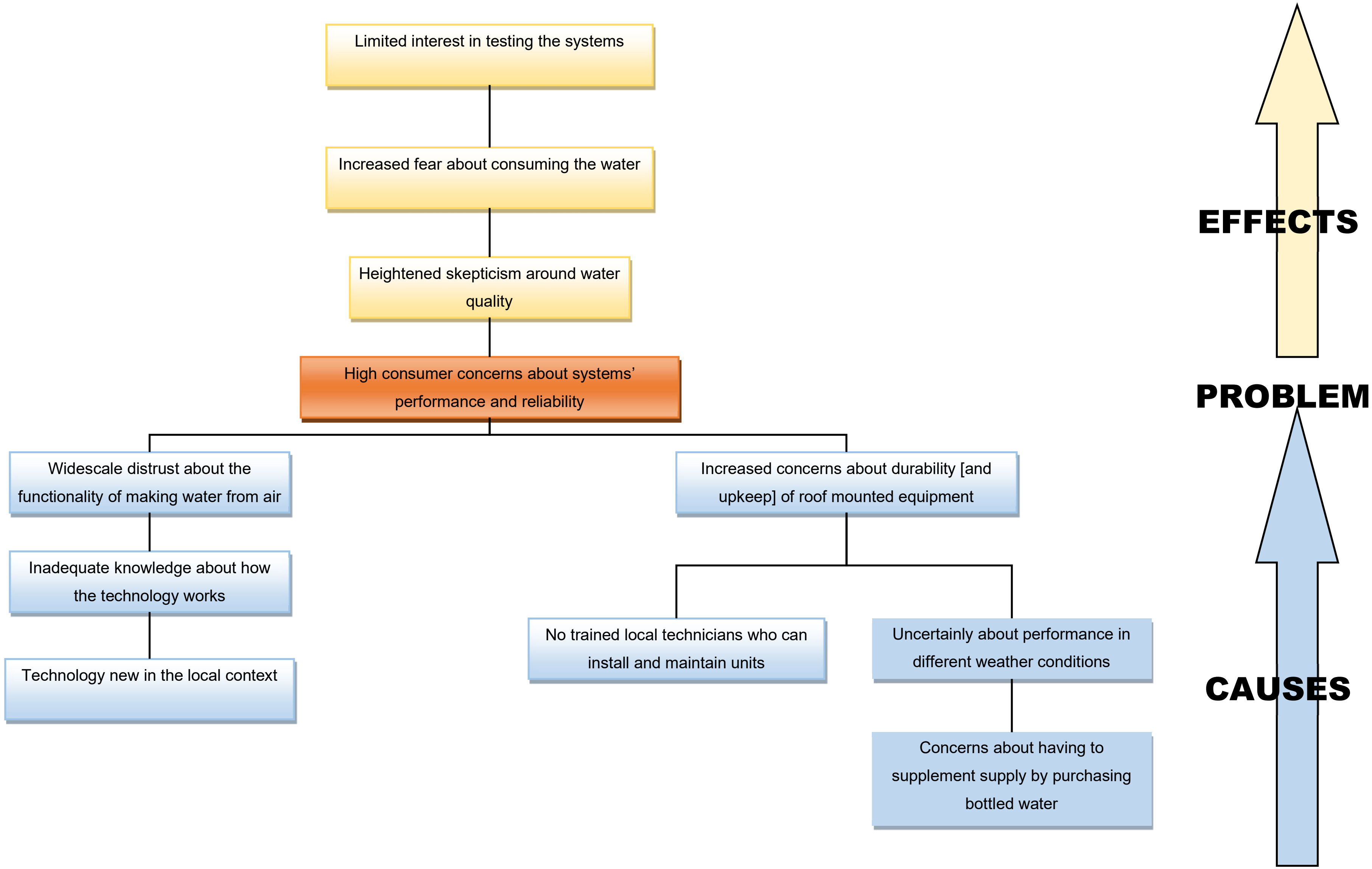
PROBLEM TREE – CONSUMERS APPREHENSIVE TO MAKE THE HIGHER INITIAL INVESTMENT IN COMPARISON TO TRADITIONAL WATER COOLERS



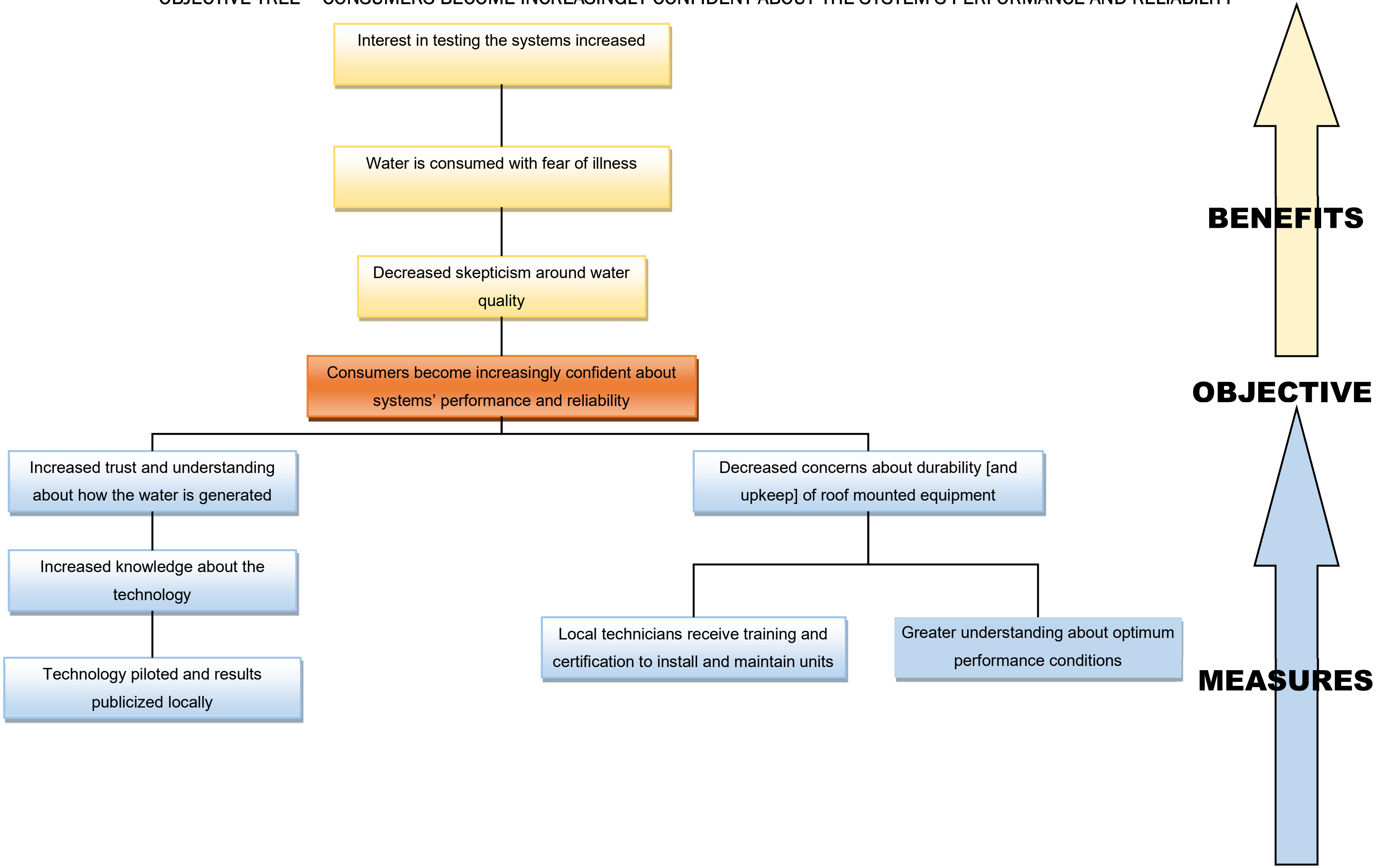
OBJECTIVE TREE – INCREASED CONSUMER WILLINGNESS TO INVEST IN AWG UNITS



PROBLEM TREE – HIGH CONSUMER CONCERNS ABOUT SYSTEMS PERFORMANCE AND RELIABILITY

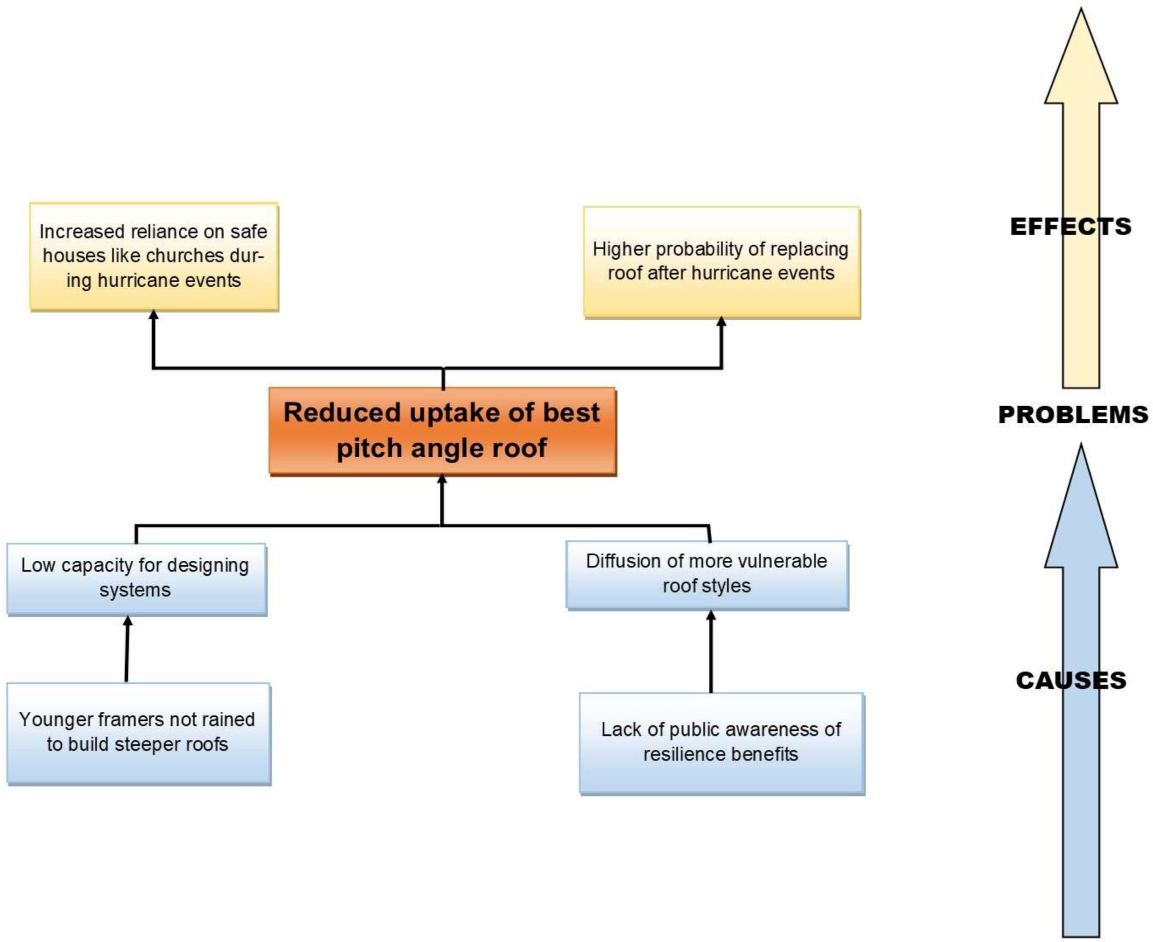


OBJECTIVE TREE – CONSUMERS BECOME INCREASINGLY CONFIDENT ABOUT THE SYSTEM'S PERFORMANCE AND RELIABILITY

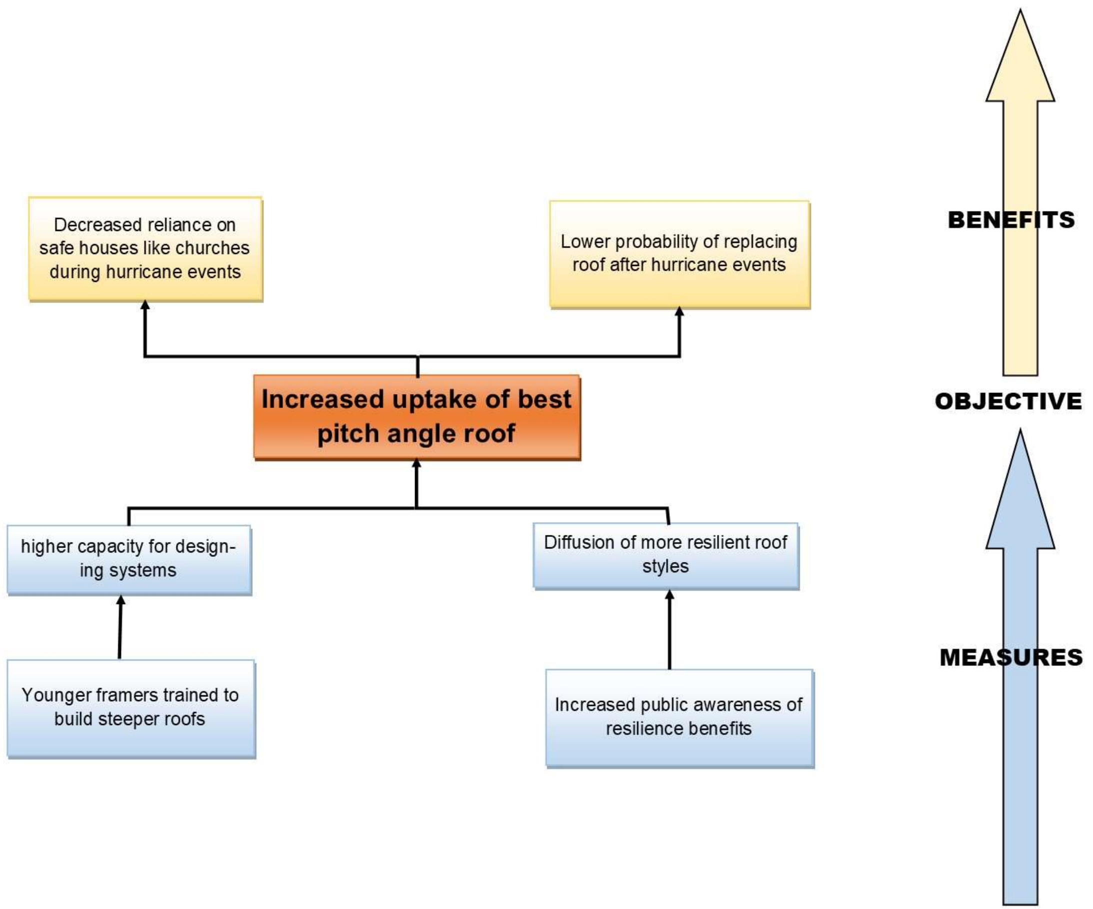


ANNEX H: LOGICAL PROBLEM AND OBJECTIVE TREES FOR BEST ROOF PITCH ANGLE

PROBLEM TREE – Reduced Uptake of Best Pitch Angle Roof



Solution TREE – Reduced Uptake of Best Pitch Angle Roof



ANNEX I: GACMO MODELLING OF LED ADAPTATION AND CFL LIGHT BULBS

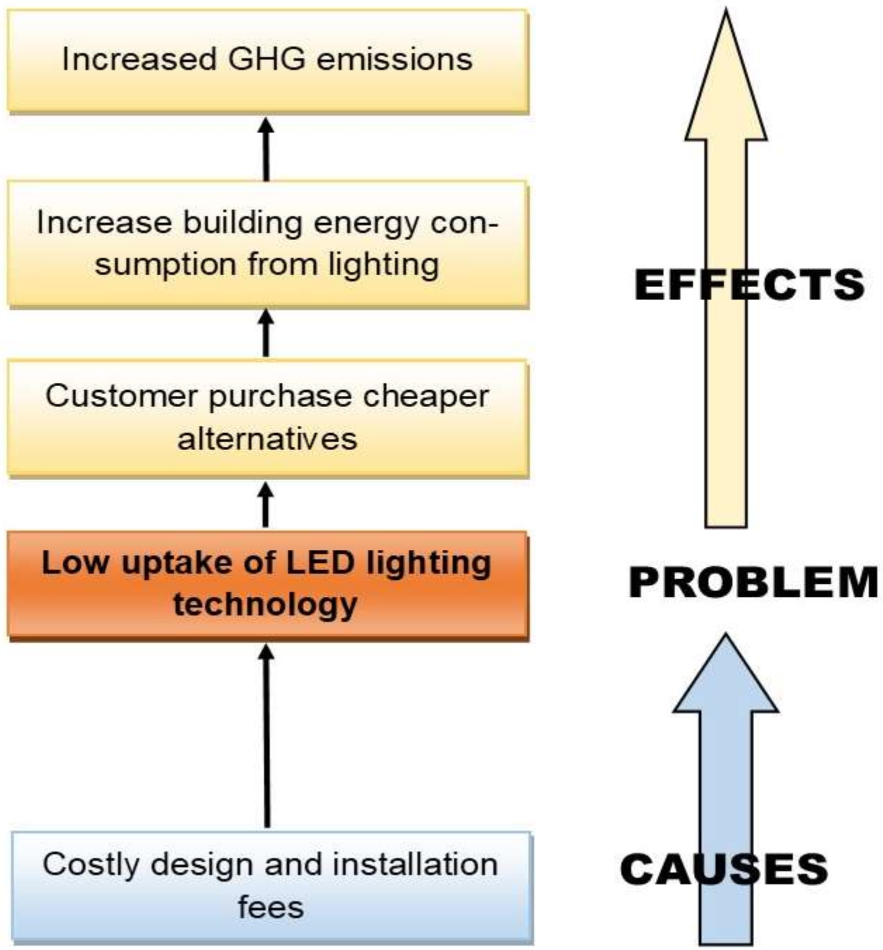
Efficient domestic lighting with LEDs (20,000 bulbs)

Costs in US$	Reduction Option	Reference Option	Increase (Red.-Ref.)
Total investment	148,148	370,000	-221,852
Project life	17.1	17.1	
Lev. investment	14,594	36,448	-21,854
Annual O&M			0
Annual electricity cost	3,457,280	25,929,600	-22,472,320
Total annual cost	3,471,874	25,966,048	-22,494,174
Annual emissions (tons)	Tons	Tons	Reduction
Fuel CO2-eq. emission	430	3,229	2,798
Other			
Total CO2-eq. emission	430	3,229	**2,798**
US$/ton CO2-eq.			**-8039.28**

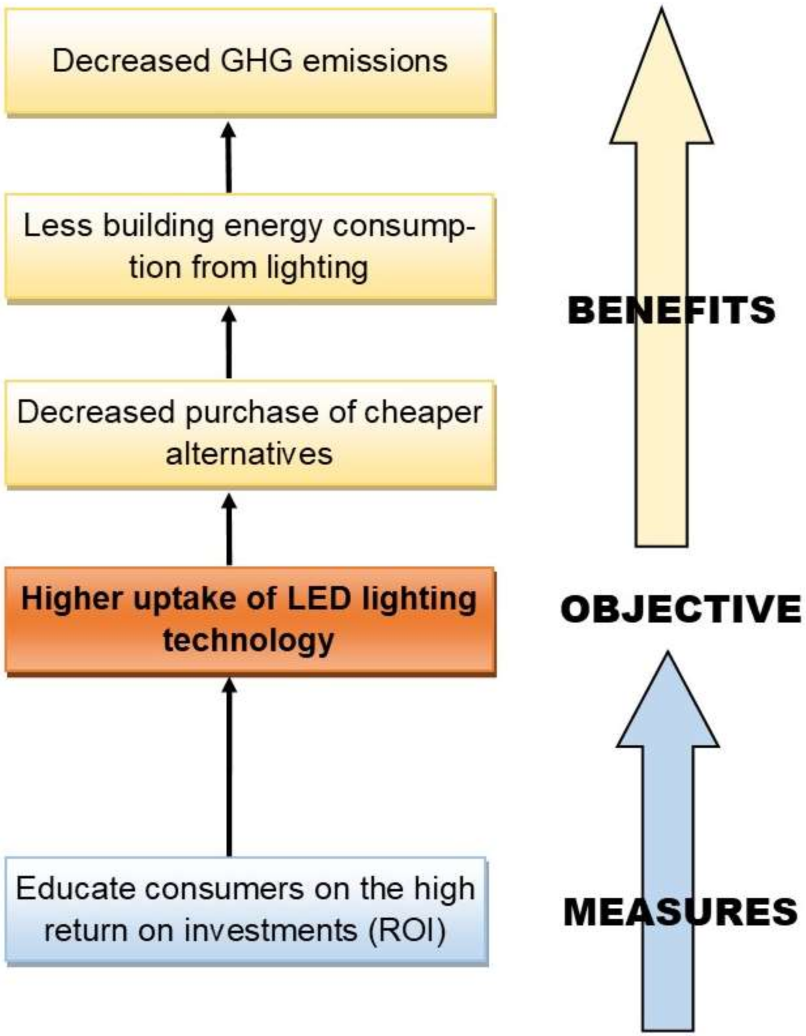
General inputs:		
Discount rate	7%	
Average electricity price	0.37	US$/kWh
CO2-eq. emission coefficient	0.75	ton CO2-eq./MWh
Grid loss	18.6%	
Reduction option: LEDs		
Average W of LED lamps	8.0	W
Daily usage	8.00	hrs
Annual import of bulps	20000	Bulps
Cost of LED	7	US$
Electricity for LED lighting	467	MWh/year
Reference option: Incandescent bulps		
Average W of replaced lamps	60.0	W
Lifetime of a incandescent	0.3	years
Lifetime of a LED	17.1	years
Number of replacements	50.0	
Price for an incandescent bulp	0.4	US$
Electricity for incandescent lighting	3504	MWh/year
Electricity saving for 20,000 lamps	3037	MWh/year

ANNEX J: LOGICAL PROBLEM AND OBJECTIVE TREES FOR LED BULBS

PROBLEM TREE – Low Uptake of LED Lighting Technology

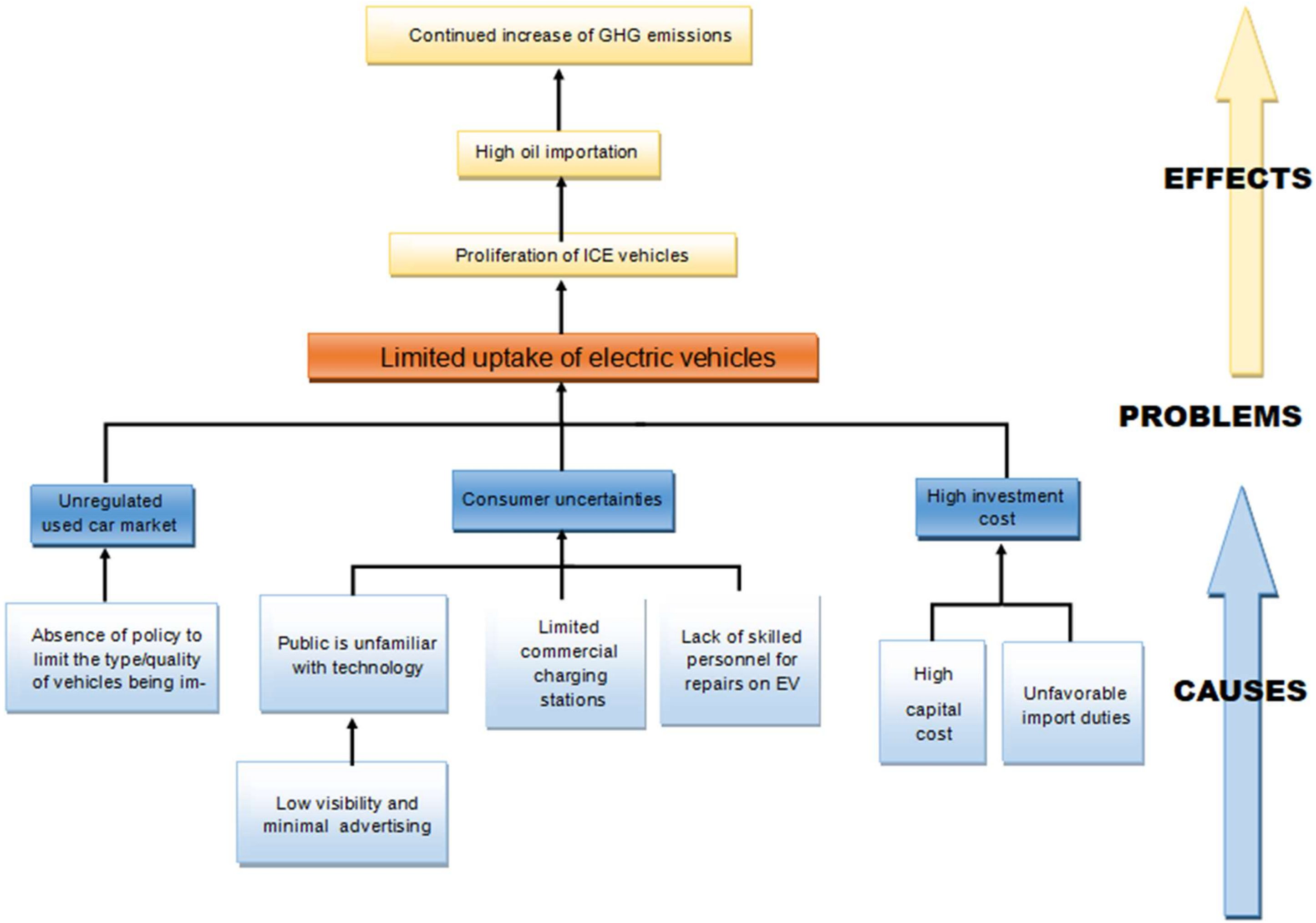


Solution TREE – Higher Uptake of LED Lighting Technology

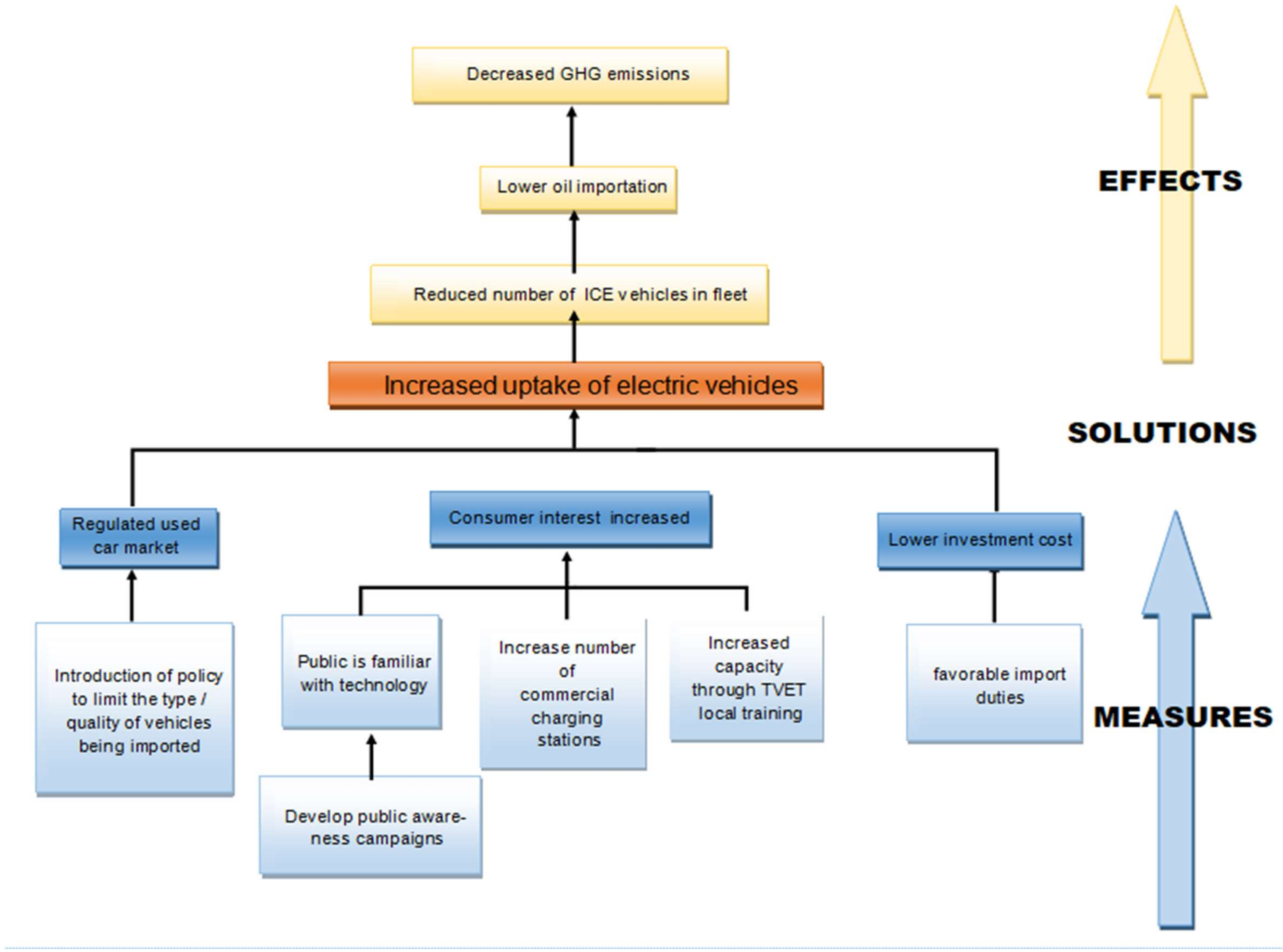


ANNEX K: LOGICAL PROBLEM AND OBJECTIVE TREES FOR ELECTRIC VEHICLES

PROBLEM TREE – Limited Uptake of Electric Vehicles

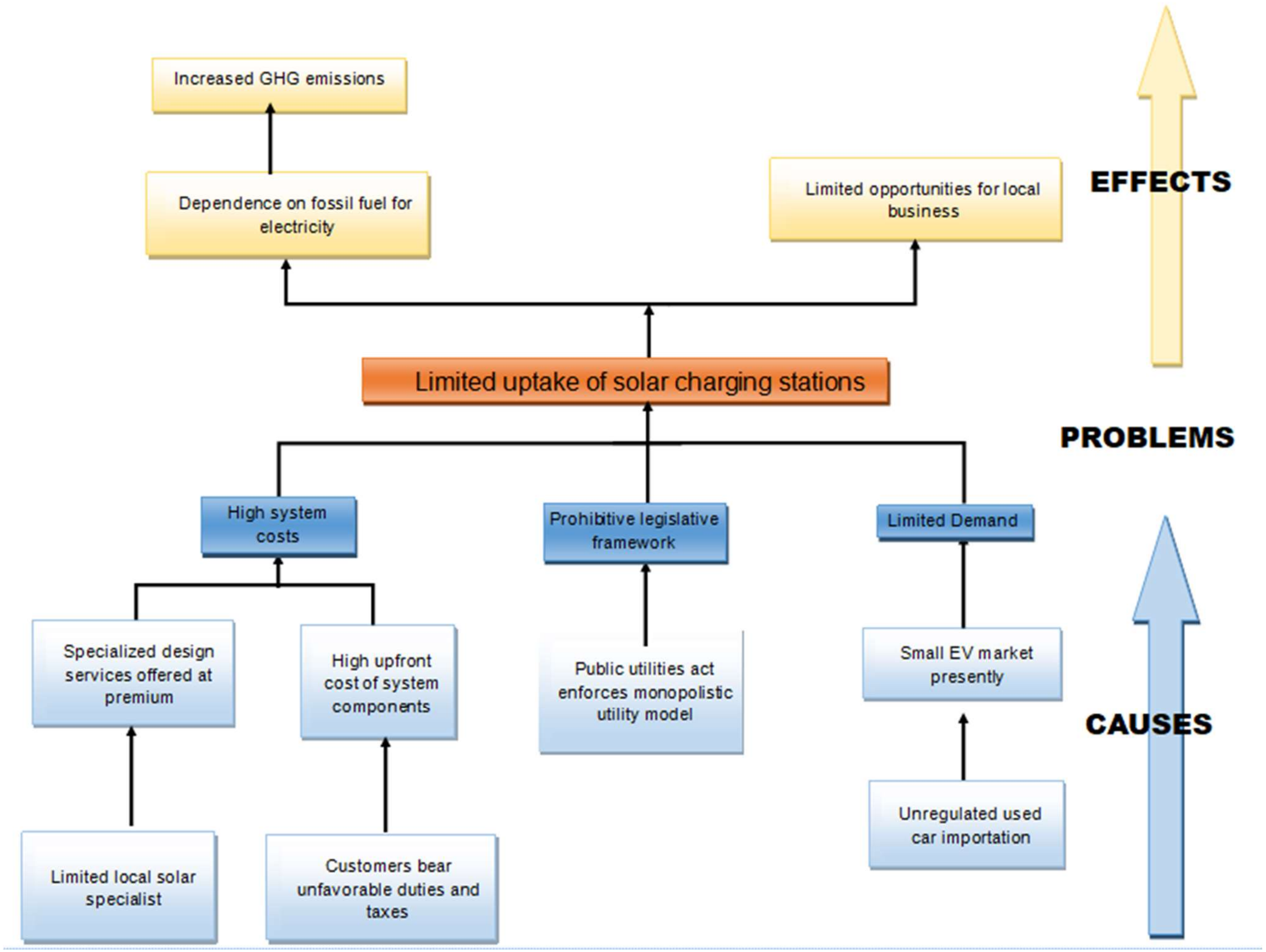


Solution TREE – Limited Uptake of Electric Vehicles

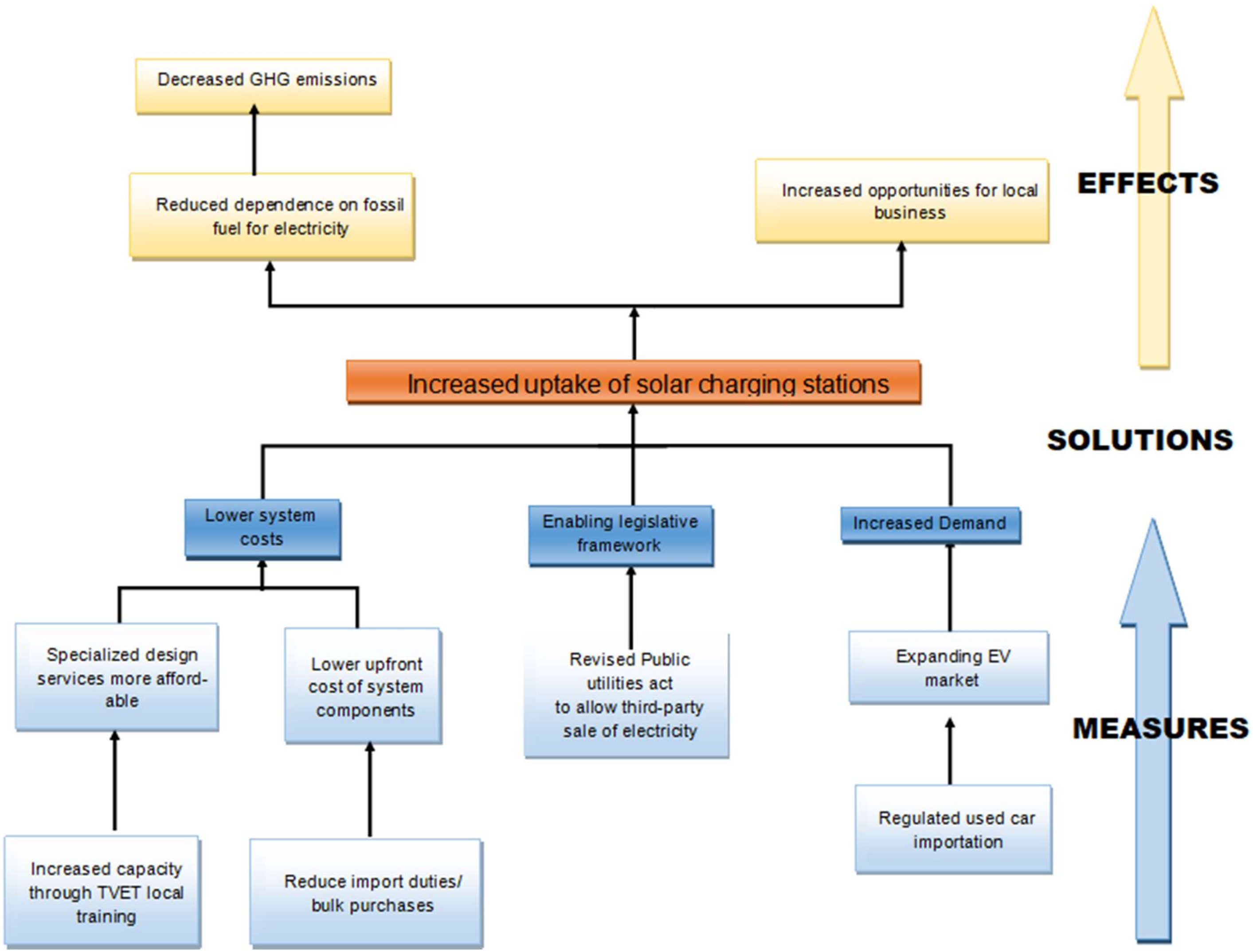


ANNEX L: LOGICAL PROBLEM AND OBJECTIVE TREES FOR SOLAR CHARGING STATION

PROBLEM TREE –Limited Uptake of Solar Charging Stations



Solution Tree – Increased Uptake of Solar Charging Stations



ANNEX M: GACMO MODELLING OF THE SOLAR CHARGING STATION UPTAKE

Solar house PVs, 1000 (5.4kW) without battery			
Costs in	Reduction	Reference	Increase
US$	Option	Option	(Red.-Ref.)
Total investment	27,000,000.0		
Project life	20.0		
Lev. investment	2,450,422.7		2,450,422.7
Annual O&M	270,000.0		270,000.0
Annual fuelcost		3,281,715.0	-3,281,715.0
Total annual cost	2,720,422.7	3,281,715.0	**-561,292.3**
Annual emissions (tons)	Tons	Tons	Reduction
Fuel CO2-eq. emission		6,873.86	6,873.86
Other			
Total CO2-eq. emission	0.00	6,873.86	**6,873.86**
US$/ton CO2-eq.			**-81.7**

Notes:
This calculation for an urban house is made for a country with an avarage daily insolation of 5 hours.

General inputs:		
Discount rate	7%	
Reference electricity price	0.37	US$/kWh
CO2-eq. emission coefficient	0.78	tCO2/MWh

Activity: Solar PV		
Size of solar PV	5400.0	kW
Size of PV	39876.9	m2
Investment in Activity	5000	US$/kW
Daily insolation	5.00	hours
Annual capacity factor	1825	Full time hours
Efficiency factor	0.9	
O&M	1.0%	Of investment
Electricity production	8869.500	MWh
Cost of electricity produced	0.307	US$/kWh
Reference option: No solar PVs		
Electricity production	8869.500	MWh

Electric cars (1000 cars) in 2025			
Costs in US$	Reduction Option	Reference Option	Increase (Red.-Ref.)
Total investment	154,000,000	112,000,000	42,000,000
Project life	15	15	
Lev. investment	16,378,329	11,911,512	4,466,817
Annual O&M	1,540,000	1,120,000	420,000
Annual fuel cost	2,453,100	3,493,714	-1,040,614
Total annual cost	20,371,429	16,525,226	**3,846,203**
Annual emissions (tons)	Tons	Tons	Reduction
Fuel CO2-eq. emission	4,973	7,983	3,011
Other			
Total CO2-eq. emission	4,973	7,983	**3,011**
US$/ton CO2-eq.			**1,277**

Notes: Batteries: Bloomber new energy Finance 2019
Test En Elbil,
Archimedes Projektet, Aalborg Kommune
Efficiency gain for electric vehicle 15% to 2025

General inputs:		
Discount rate	7%	
Annual distance	12,000	km
Activity	5,000	Cars
Reduction option: Electric cars		
Investment in vehicle	30,800	US$
Investment in charging station	-	US$
Size of battery	40	kWh
Investment in battery	-	US$/kWh
Annual O&M	1.0%	of investment
Electricity consumption	9.0	km/kWh
Total electricity consumption	6,630	MWh
Reference electricity price	0.37	US$/kWh
CO2-eq. emission coefficient	0.75	tCO2/MWh
Emissions from electricity	4,973	tCO2
Economic efficiency	1.70	US$/km
Reference option: Normal gasoline cars		
Energy consumption	17.5	km/l
Investment in vehicle	22,400	US$
Annual O&M	1.0%	of investment
Gasoline price	1.02	US$/liter
Total gasoline consumption	3.43	Million liters
1000 l gasoline =	33.6	GJ
CO2-eq. emission coefficient	69.3	kgCO2-eq./GJ
Emissions from gasoline	7,983	tCO2
Economic efficiency	1.38	US$/km

ANNEX N: FIGURES OF ANTIGUA AND BARBUDA'S VEHICULAR FLEET

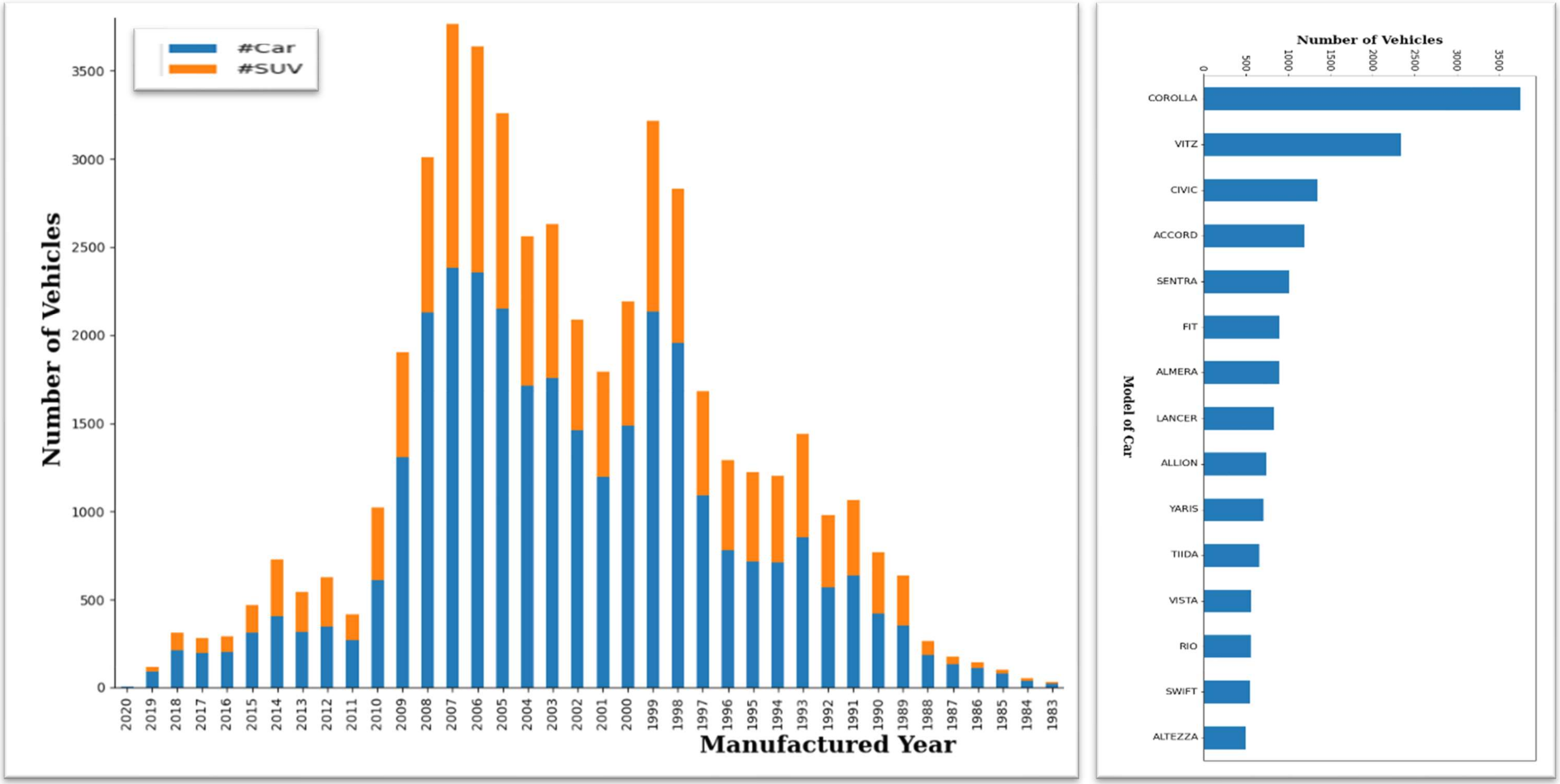


Figure 5: Age distribution of cars and SUVs vehicle fleet in Antigua (left), Most popular vehicle model as 2020 data[48]

[48] Produced using data from the Antigua and Barbuda Transport Board

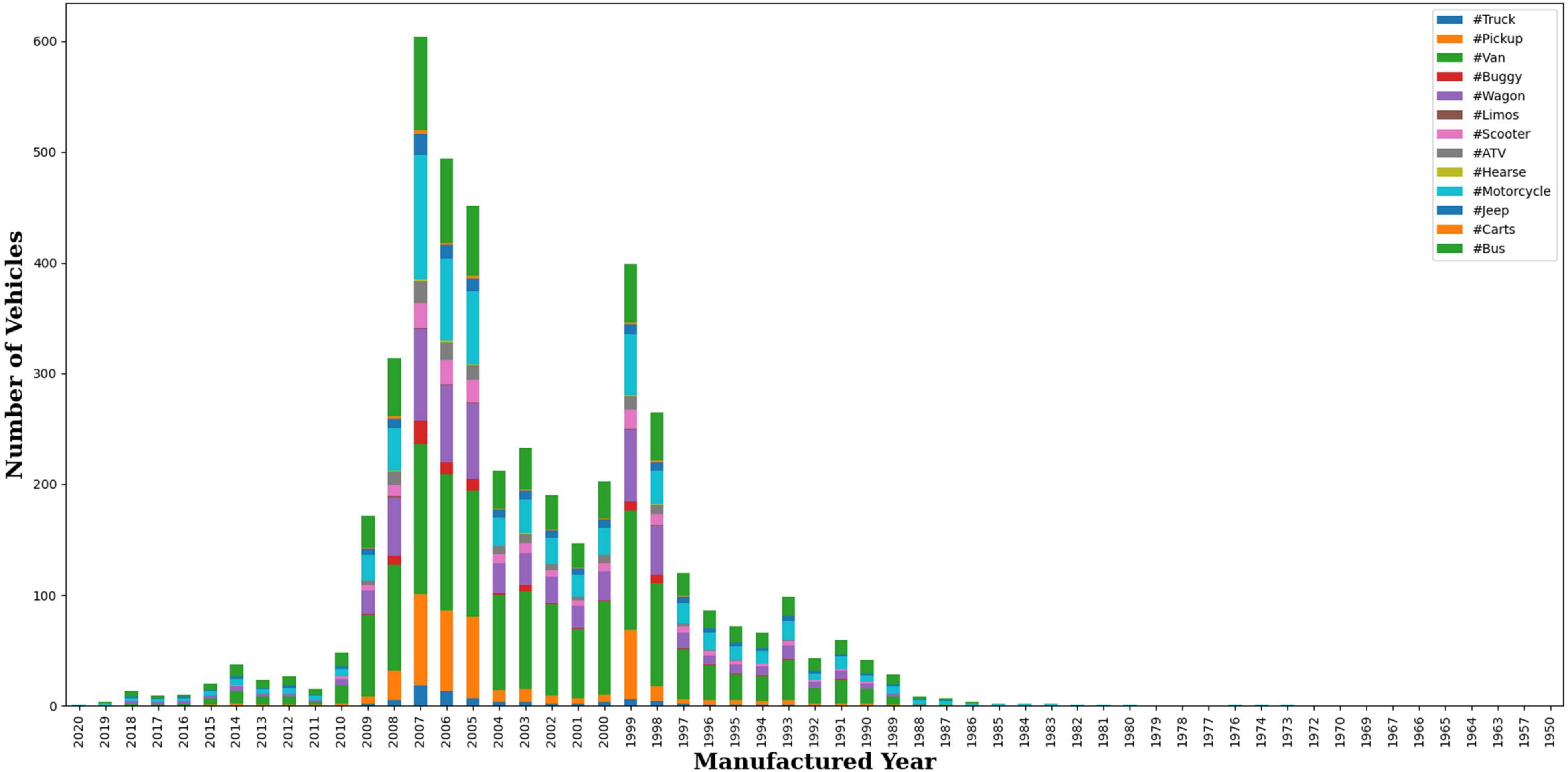


Figure 6: Age distribution of the vehicle fleet in Antigua as of 2020[49]

[49] Produced using data from the Antigua and Barbuda Transport Board

ANNEX O: GACMO MODELLING OF ELECTRIC VEHICLE ADAPTATION UP TO THE YEAR 2030

Electric cars (1000 cars) in 2020			
Costs in US$	Reduction Option	Reference Option	Increase (Red.-Ref.)
Total investment	132,000,000	96,000,000	36,000,000
Project life	15	15	
Lev. investment	14,038,567	10,209,867	3,828,700
Annual O&M	660,000	960,000	-300,000
Annual fuel cost	1,731,600	2,183,571	-451,971
Total annual cost	16,430,167	13,353,439	**3,076,729**
Annual emissions (tons)	Tons	Tons	Reduction
Fuel CO2-eq. emission	3,510	4,990	1,480
Other			
Total CO2-eq. emission	3,510	4,990	**1,480**
US$/ton CO2-eq.			**2,079**

General inputs:		
Discount rate	7%	
Annual distance	12,000	km
Activity	3,000	Cars
Reduction option: Electric cars		
Investment in vehicle	44,000	US$
Investment in charging station	-	US$
Size of battery	40	kWh
Investment in battery	-	US$/kWh
Annual O&M	0.5%	of investment
Electricity consumption	7.7	km/kWh
Total electricity consumption	4,680	MWh
Reference electricity price	0.37	US$/kWh
CO2-eq. emission coefficient	0.75	tCO2/MWh
Emissions from electricity	3,510	tCO2
Economic efficiency	1.37	US$/km
Reference option: Normal gasoline cars		
Energy consumption	16.8	km/l
Investment in vehicle	32,000	US$
Annual O&M	1.0%	of investment
Gasoline price	1.02	US$/liter
Total gasoline consumption	2.14	Million liters
1000 l gasoline =	33.6	GJ
CO2-eq. emission coefficient	69.3	kgCO2-eq./GJ
Emissions from gasoline	4,990	tCO2
Economic efficiency	1.11	US$/km