# KOFORIDUA TECHNICAL UNIVERSITY

## CHINA SOUTH-SOUTH COOPERATION ON RENEWABLE ENERGY TECHNOLOGY TRANSFER (RETT) PROJECT

**TOPIC:**

**FINDINGS OF THE *PRE-FEASIBILITY STUDIES ON POTENTIAL SOLAR IRRIGATION SCHEMES AT SELECTED GIDA SITES IN THE COASTAL REGIONS***

DATE: 13TH JANUARY 2017

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# OUTLINE OF THE PRESENTATION

- INTRODUCTION
- AIM AND OBJECTIVES
- CRITERIA DEVELOPMENT
- SHORTLISTED PROJECT AND THEIR CHARACTERISTICS
- FINANCIALS
- COST BENEFIT ANALYSIS
- BUSINESS MODELS
- CONCLUSIONS

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# INTRODUCTION

- The RETT project is a collaborative effort between the Energy Commission of Ghana, Ministry of Science and Technology of China and UNDP offices in Ghana and China.
- The overall aim of the project is to facilitate the exchange of expertise and Renewable Energy Technologies between China and Ghana.

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# INTRODUCTION cont'd

- The project is limited to the following Renewable Energy Technologies:
  - Solar and wind for productive use;
  - Biogas;
  - Improved cookstoves;
  - Mini-Hydro.
- The scope of the project is in 8 different phases of which the current assignment focuses on the first three phases.

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# AIMS AND OBJECTIVES

- The RETT project seeks to explore opportunities in deploying solar PV and thermal installations for productive use.
- Specifically, the project seeks to:
  - Phase 1- Develop criteria for selection of solar/wind technologies
  - Phase 2- Select a suitable solar/wind technology to be transferred from China to Ghana using the criteria developed
  - Phase 3- Conduct a pre-feasibility study on selected sites

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# CRITERIA DEVELOPMENT (METHODS)

- A consultative workshop was organized by the Energy Commission among the selected research institutions.
- At the workshop, a list of main and sub criteria were developed after an intensive team work.

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# CRITERIA DEVELOPMENT (List of criteria and sub criteria)

| Main Criteria | Sub Criteria |
|---|---|
| Economical | Initial Cost (supply side) |
| | Operation & Maintenance Cost |
| | Market Availability |
| | Loan Assessment to obtain Technology |
| | Affordability (demand side) |
| | Creation of Jobs (PPP, gov.) |
| | Economic Sustainability (gov. projects) |
| | Payback Period |
| | Substitutes/Alternative Technology |

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# CRITERIA DEVELOPMENT (List of criteria and sub criteria)

| | |
|---|---|
| Technical | Resource Availability (solar/wind) |
| | Land Availability |
| | Site/Location Accessibility |
| | Durability/Life Span |
| | Performance of Technology under warm Humid Climates |
| | Technical Expertise to install and repair the Technology |
| | Ease of scaling-up Technology |
| | Availability of Materials/Spare Parts |
| | Ease of Local Replication/Manufacturing |
| | Technology Maturity |
| | Ease of use of Technology |

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# CRITERIA DEVELOPMENT (List of criteria and sub criteria)

| | |
|---|---|
| **Environmental** | Disposal of waste of the Technology |
| | Decommissioning |
| | Health issues in using Technology |
| | Pollution levels -impact of Technology on the Environment/Climate Change |

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# CRITERIA DEVELOPMENT (List of criteria and sub criteria)

| | |
|---|---|
| **Socio-political** | Acceptability of Technology in the Community |
| | Adoption of Technology to other social settings |
| | Ease of obtaining License to implement project |
| | Specific Policies relating to the Technology |
| | Capacity Building/Skills Development potential |
| | Health improvement of using Technology |
| | Contribution of use of Technology to GDP |
| | Promotion of Sub-Regional Cooperation |
| | Tax Incentives/Exemptions |

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# TECHNOLOGY SELECTION (Meeting with the Chinese delegation)

- A consultative workshop between a Chinese delegation and Ghanaian counterpart was organized by the Energy Commission.
- The workshop focused on the review of readily available technologies in China that could be transferred to Ghana.

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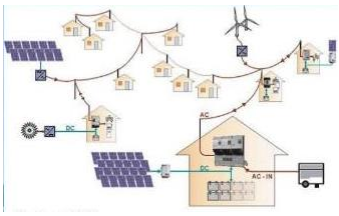
# TECHNOLOGY SELECTION (Outcome of meeting with the Chinese delegation)

Solar PV Air Conditioner

Battery and Phone Charging System



Mini-grid Solar System

Solar Street Lighting

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# TECHNOLOGY SELECTION (Outcome of meeting with the Chinese delegation) cont'd

Solar PV Lantern

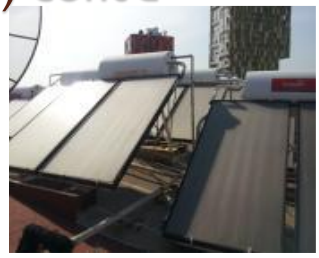
Solar Refrigeration

Solar Water Pumping for Irrigation

Solar Water Pumping for Domestic Use

# TECHNOLOGY SELECTION (Outcome of meeting with the Chinese delegation) cont'd

Solar Drying for Agricultural Purposes



Flat Plate Solar Water Heating

Evacuated Tubes Solar Water Heating System


Absorption Chillers

# TECHNOLOGY SELECTION (Outcome of meeting with the Chinese delegation) cont'd

Solar Thermal Cooker

Solar Water Desalination


Solar Home Systems for all loads

Solar Emergency Power System

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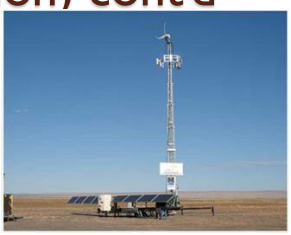
# TECHNOLOGY SELECTION (Outcome of meeting with the Chinese delegation) cont'd

Solar Powered Tri-motorcycle



Mobile Solar Powered Platform

Cloud Thermal Solar Hot Water System

Wind/Photovoltaic Hybrid System for Irrigation

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# TECHNOLOGY SELECTION (Outcome of meeting with the Chinese delegation) cont'd

Trough Solar Energy Power Generation Technology



# TECHNOLOGY SELECTION (Ranking of selected technologies)

- The Decision Matrix Technique, an aspect of Multi-Criteria Decision Analysis (MCDA) was used to rank the various solar/wind energy technologies.
- The first stage of the technique was to give weight to the selected criteria using experts' knowledge.
- The teams from Koforidua Tech. Uni. and KNUST met on a number occasions to deliberate on the weighting of the main and sub criteria.

# TECHNOLOGY SELECTION (Ranking of selected technologies) cont'd

| Main Criteria | Weight | Sub Criteria | Weight |
|---|---|---|---|
| Economical | 0.4 | Initial Cost (supply side) | 0.2 |
| | | Maintenance & Operation Cost | 0.05 |
| | | Market Availability | 0.1 |
| | | Loan Assessment to obtain Technology | 0.1 |
| | | Affordability (demand side) | 0.15 |
| | | Creation of Jobs (PPP, gov.) | 0.15 |
| | | Economic Sustainability (gov. projects) | 0.1 |
| | | Payback Period | 0.1 |
| | | Substitutes/Alternative Technology | 0.05 |

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# TECHNOLOGY SELECTION (Ranking of selected technologies) cont'd

| | | | |
|---|---|---|---|
| Technical | 0.3 | Resource Availability (solar/wind) | 0.15 |
| | | Land Availability | 0.1 |
| | | Site/Location Accessibility | 0.05 |
| | | Durability/Life Span | 0.05 |
| | | Performance of Technology under warm Humid Climates | 0.1 |
| | | Technical Expertise to install and repair the Technology | 0.15 |
| | | Ease of scaling-up Technology | 0.05 |
| | | Availability of Materials/Spare Parts | 0.05 |
| | | Ease of Local Replication/Manufacturing | 0.15 |
| | | Technology Maturity | 0.05 |
| | | Ease of use of Technology | 0.1 |

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# TECHNOLOGY SELECTION (Ranking of selected technologies) cont'd

| | | | |
|---|---|---|---|
| **Environmental** | 0.2 | Disposal of waste of the Technology | 0.2 |
| | | Decommissioning | 0.2 |
| | | Health issues in using Technology | 0.2 |
| | | Pollution levels - impact of Technology on the Environment/Climate Change | 0.4 |

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# TECHNOLOGY SELECTION (Ranking of selected technologies) cont'd

| | | | |
|---|---|---|---|
| **Socio-political** | **0.1** | **Acceptability of Technology in the Community** | **0.05** |
| | | Adoption of Technology to other social settings | 0.05 |
| | | Ease of obtaining License to implement project | 0.15 |
| | | Specific Policies relating to the Technology | 0.1 |
| | | Capacity Building/Skills Development potential | 0.15 |
| | | Health improvement of using Technology | 0.1 |
| | | Contribution of use of Technology to GDP | 0.2 |
| | | Promotion of Sub-Regional Cooperation | 0.1 |
| | | Tax Incentives/Exemptions | 0.1 |

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# TECHNOLOGY SELECTION (Ranking of selected technologies)

- The last stage of the technique was to rank the technologies using the weighted main criteria and sub-criteria.
- Each of the technologies was rated against the sub-criteria using a scale of 1-5 where 1-low, 2-below average, 3-average, 4-above average and 5-high.
- The scale assigned to each technology was multiplied by the weights of the sub criteria and its corresponding main criteria.
- The process was repeated for all the sub-criteria and summed up giving the cumulative weight of the technology for the main criteria
- The total cumulative weight was the sum of cumulative weights of the four main criteria.

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# TECHNOLOGY SELECTION (Ranking of selected technologies)

| Sample procedure for ranking a technology | | | | | |
|---|---|---|---|---|---|
| **Criteria** | **Weight (a)** | **Sub-criteria** | **Weight (b)** | **Scale (c)** | a × b × c |
| Environment | 0.2 | disposal of waste of the technology | 0.2 | 4 | 0.16 |
| | | Decommissioning | 0.2 | 5 | 0.2 |
| | | Health issues in using technology | 0.2 | 5 | 0.2 |
| | | pollution levels - impact of technology on environment/climate change | 0.4 | 5 | 0.4 |
| **Cumulated weight** | | | | | **0.96** |

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# TECHNOLOGY SELECTION
## (Ranking of selected technologies)

| Technology | Total Cumulative Weight | Rank |
|---|---|---|
| Solar Water Pumping System for Irrigation | 3.91 | 1 |
| Solar Street Lighting | 3.62 | 2 |
| Solar drying for Agricultural Purposes | 3.45 | 3 |
| Solar Water Desalination | 3.29 | 4 |
| Evacuated Tubes Solar Water Heating System | 3.23 | 5 |
| Solar Lantern | 3.13 | 6 |
| Battery and Phone Charging System | 3.02 | 7 |
| Solar Home Systems (All Loads) | 2.93 | 8 |
| Solar Thermal Cookers | 2.91 | 9 |
| Solar Refrigeration | 2.91 | 10 |
| Wind-photovoltaic Hybrid System for Irrigation | 2.86 | 11 |

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# TECHNOLOGY SELECTION
## (Ranking of selected technologies)

| Technology | Total cumulative Weight | Rank |
|---|---|---|
| Solar Powered Tri-Motorcycle for Transportation | 2.73 | 12 |
| Flat Plate Solar Water Heating | 2.68 | 13 |
| Solar PV Air-conditioning | 2.51 | 14 |
| Mobile Solar Powered Platform | 2.49 | 15 |
| Solar Water Pumping for Domestic Uses | 2.35 | 16 |
| Cloud Thermal Solar Hot Water System | 2.28 | 17 |
| Solar Powered Thermally Driven Chillers | 2.26 | 18 |
| Solar Emergency Power Systems | 2.26 | 19 |
| Trough Solar Energy Power Generation Technology | 2.17 | 20 |
| Mini Grid Solar System | 2.05 | 21 |

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# Standards for solar PV systems

| S/N | Description | Standard |
|---|---|---|
| 1. | Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 1: Test requirements | IEC-61215-1 |
| 2. | Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 2: Test procedures | IEC-61215-2 |
| 3. | Photovoltaic (PV) module safety qualification | IEC 61730-2 |
| 4. | Measurement of photovoltaic current-voltage characteristics | IEC-60904-1 |
| 5. | Photovoltaic system performance - Part 1: Monitoring | IEC 61724-1 |
| 6. | Photovoltaic (PV) systems - Requirements for testing, documentation and maintenance - Part 2: Grid connected systems - Maintenance of PV systems | IEC 62446-2 |
| 7. | Occupational health and safety management systems Requirements with guidance for use | ISO/DIS 45001 |
| | | |

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# Shortlisted projects and their characteristics

- Energy Commission in conjunction with GIDA identified four Irrigation Schemes for the pre-feasibility study.
- The Schemes are:
  - DAWHENYA IRRIGATION SCHEME
  - DORDOEKOPE SMALL FARMS IRRIGATION SCHEME
  - DORDOEKOPE SMALL SCALE IRRIGATION SCHEME
  - WEIJA IRRIGATION SCHEME

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# DAWHENYA IRRIGATION SCHEME (Description of the system)

- It has a territorial integrity of 2800 ha of which 400 ha is irrigable.
- However, only 200 ha has been developed while 180 ha has been irrigated.
- The demographic composition of the site consist of 237 farmers.
- Rice is the major crop that is cultivated by the farmers during the two cropping seasons

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# DAWHENYA IRRIGATION SCHEME (Description of the system) cont'd

- Water from the dam is pumped to the reservoir having a capacity of 18000 $m^3$ using two pumps at a time with a third pump on standby.
- It takes 24 hours for the reservoir to be refilled when empty using two pumps running are at full capacity.
- The pumps' operating hours is in the range of 500-600 hrs/month.
- The pumps were replaced by Korea International Cooperation Agency (KOICA) in 2014.

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# DAWHENYA IRRIGATION SCHEME (Description of the system) cont'd

Water intake point

Higen 3-ϕ pumps

Rice field

Reservoir

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# Dordoekope Small Farms Irrigation Scheme (Description of the system)

- The site has a total irrigable land area of 280 ha with 87 ha developed.
- The site has 65 farmers out of which 20 are women and it is managed by a seven (7) member committee.
- The farmers cultivate fruits and vegetables including Onions, Tomatoes, Pepper, Okro and Water melon.
- Water is pumped from the Angor River to a 2500 $m^3$ reservoir

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# Dordoekope Small Farms Irrigation Scheme (Description of the system) cont'd

- The water is distributed to the farmlands through canals.
- Some farmers employ pumps for the distribution on their individual farms.
- Initially, four Grundfos pumps were installed however only one MAS 3-phase pump is currently in operation .
- Pumping of water is done every four (4) days and it takes three (3) days to refill the reservoir when empty.

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# Dordoekope Small Farms Irrigation Scheme (Description of the system) cont'd

Lettuce field

Water source

Water intake point

Pumps

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## Dordoekope Small Scale Irrigation Scheme (Description of the system)

- The irrigated land is124 ha.
- The site has about 100 farmers out of which 15 are women and is managed by a 7 member committee.
- Major crops cultivated by farmers are fruits and vegetables.

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## Dordoekope Small Scale Irrigation Scheme cont'd (Description of the system) cont'd

- Until recently, four 3-phase Grundfos pumps transport water from the Angor River to a 5000$m^3$ reservoir.
- Currently only two pumps are in operation. The pumps are operated for 11 hrs/day for every other two days.

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# Dordoekope Small Scale Irrigation Scheme (Description of the system) cont'd

Cabbage field

Reservoir

Pumps

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# Weija Irrigation Scheme (Description of the system)

- Currently, 220 ha have been developed whiles 195 ha is irrigated.
- The site has 230 farmers who cultivate vegetables such Tomatoes, Pepper, Tinda, Marrow and Okro
- The crops are cultivated in three cropping seasons.
- The site has two pumping stations that employs pump gravity pump with sprinklers for irrigation.
- The first station uses two pumps to transport water against gravity to an intake orifice.

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## Weija Irrigation Scheme (Description of the system) cont'd

- The water flows naturally through canals to a night storage reservoir having a capacity of 15,000 $m^3$.
- It takes 5 hours to be refilled.
- The second pump station then transports the water from the reservoir to the farm lands.
- A sprinkler system on each farm land distributes the water onto the crops.

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## Weija Irrigation Scheme (Description of the system) cont'd

- The first pump station is fitted with two pumps and operates 6-8 hrs/day with a discharge of 400$m^3$/h.
- The pump in the second station operates five days in a week with a discharge of 200 $m^3$/h.

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# Weija Irrigation Scheme (Description of the system) cont'd

Pump

Reservoir

Okro field

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# Current power situation at the Irrigation Schemes

| Facility | Source of Electricity | Average monthly energy consumption (kWh) | Outstanding debt ($) |
|---|---|---|---|
| Dawhenya Irrigation Scheme | National Grid | 22237.4 | 106,104.74 |
| Dordoekope Small Farms Irrigation Scheme | National Grid | 885.6 | 9,536.47 |
| Dordoekope Small Scale Irrigation Scheme | National Grid | 1030.97 | 4,412.40 |
| Weija Irrigation Scheme | National Grid | 4119.01 | 4,237.42 |

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# Cash flow of the Irrigation Schemes

| Facility | Irrigation Service Charge, ISC ($) | % of ISC used for paying electricity | Total Revenue ($/ha) | Total Expenditure ($/ha) | Total Profit/ha |
|---|---|---|---|---|---|
| Dawhenya Irrigation Scheme | 679.74 | 70 | 2599.56 | 1768.9 | 830.66 |
| Dordoekope Small Farms Irrigation Scheme | 120.35 | 80 | 2262.58 | 722.10 | 1540.48 |
| Dordoekope Small Scale Irrigation Scheme | 120.35 | 80 | 2382.92 | 601.75 | 1781.18 |
| Weija Irrigation Scheme | 601.75 | 80 | 2373.3 | 1239.12 | 1134.18 |

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# Solar PV system design (Parameters and assumptions)

| |
|---|
| Peak Sun Hours |
| Head (m) |
| One day water demand ($m^3$) |
| Flow rate ($m^3/h$) |
| Needed water power (kW) |
| Motor efficiency |
| Pump efficiency |
| Break power efficiency |
| Panel capacity (kW) |
| Operating hours of pumps (h)/day |
| Energy demand per day (Wh) |

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## Solar PV system design (Equation used)

Panel capacity=

$$\frac{9.8 \times F \times H}{\lambda_m \times \lambda_p \times \lambda_b \times 0.8}(W)$$

Where $\lambda_m$ is the motor efficiency
F is the flow rate
H is the head
$\lambda_p$ is the pump efficiency
$\lambda_b$ is the break power efficiency.

Source: Asai K., 2010.

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## Solar PV system design (Determination of the number of modules and inverters required)

Step I: Calculate the max. allowable voltage of modules per string

Step II: Multiply the max. inverter's voltage by 0.95 to give a 5% safety margin

Step III: Divide Step II by Step I to determine the max allowable modules needed per string.

Step IV: Divide the inverter's max. DC current by the short circuit current of the module to determine the number of strings the inverter can accommodate

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# Solar PV system design (Determination of the number of panels and inverters required)

Step V: Multiply Step III by Step IV to determine the number of modules the inverter can accommodate

Step VI: Divide the total power capacity of the system by the module capacity to determine the total number of modules needed.

Step VII: Divide Step VI by Step V to determine the total number inverters required.

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# Solar PV system design (Modules and inverters required for each of the schemes)

| Facility | Total power capacity of the system (kW) | Number of modules required (using a DUSOL 300$W_p$ module) | Number of inverters required (using SMA 17000 TL inverter) |
|---|---|---|---|
| Dawhenya Irrigation Scheme | 47.02 | 157 | 2 |
| Dordoekope Small Farms Irrigation Scheme | 25.25 | 85 | 1 |
| Dordoekope Small Scale Irrigation Scheme | 37.88 | 127 | 2 |
| Weija Irrigation Scheme (Pump Station 1) | 145.8 | 487 | 5 |
| Weija Irrigation Scheme (Pump Station 2) | 23.3 | 78 | 1 |

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# Solar PV system design (Equipment and cost estimates)

| Facility | Dawhenya Irrigation Scheme | Dordoekope Small Farms Irrigation Scheme | Dordoekope Small Scale Irrigation Scheme | Weija Irrigation Scheme (Pump Station 1) | Weija Irrigation Scheme (Pump Station 2) |
|---|---|---|---|---|---|
| Panels (DUSOL-300 P) | 28,900.56 | 15,646.8 | 23,378.16 | 89,646.96 | 14,358.24 |
| Inverter (SMA 17000TL) | 23,120.00 | 11,560 | 23,120.00 | 57,800 | 11,560 |
| Accessories ( Cables, DC & AC disconnects, junction boxes) | 2,601.03 | 1,360.34 | 2,324.91 | 7,372.35 | 1,295.9 |
| Transportation, Structure & Installation cost | 20,808.22 | 10,882.72 | 18,599.26 | 58,978.78 | 10,367.3 |
| Miscellaneous (grid connection etc.) | 520.21 | 272.068 | 464.98 | 1,474.47 | 259.18 |
| **Total cost ($)** | **75,950.02** | **39,721.93** | **67,887.31** | **215,272.56** | **37,840.63** |

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# Solar PV system design (Cost Benefit Analysis)

| Financial indicator | Dawhenya Irrigation Scheme | Dordoekope Small Farms Irrigation Scheme | Dordoekope Small Scale Irrigation Scheme | Weija Irrigation Scheme |
|---|---|---|---|---|
| Total capital cost of PV system ($) | 75,950.02 | 39,721.93 | 67,887.31 | 253,113.19 |
| Payback period (years) | 1.54 | 12.47 | 14.95 | 4.72 |
| Cost ($)/kWh (Payback period) | 0.7012 | 0.0919 | 0.0908 | 0.0805 |
| Cost ($)/kWh (Assuming a 25 year scheme life) | 0.0449 | 0.0477 | 0.0543 | 0.0158 |

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# Business models

**Investment by Farmer Association with subsidy from Government**

| Stakeholders | Percentage of contribution | Source of funding |
|---|---|---|
| Farmer Association | 20 | Land, labour and loan |
| Government subsidy | 80 | Grant |

**Investment by Private Investor and the Community**

| Stakeholders | Percentage of contribution | Source of funding |
|---|---|---|
| **Private Sector** | 80 | Private fund |
| **Community Support** | 20 | Land, Low interest loan |

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# Business models cont'd

**Investment by the Private Sector and Government**

| Stakeholders | Percentage of contribution | Source of funding |
|---|---|---|
| **Private Sector** | 50 | Private fund |
| **Government** | 50 | Budget, low interest loan |

**Investment Private Sector, Government and the Community**

| Stakeholders | Percentage of contribution | Source of funding |
|---|---|---|
| **Private Sector** | 40 | Private fund |
| **Government** | 40 | Budget, low interest loan |
| **Community** | 20 | Land, labour |

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# Business models cont'd

- Investment by Private Investor only
  - Build Operate and Transfer (BOT)
  - Build Own Lease and Transfer (BOLT)
  - Build Own Operate and Transfer (BOOT)

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# Conclusions

- Four main criteria with its sub criteria were developed and used to rank the solar/wind technologies
- Twenty one (21) solar/wind technologies were identified as transferrable from China to Ghana.
- Solar Water Pumping System for Irrigation ranked as the most suitable technology that can be transferred from China to Ghana.
- The pre-feasibility study assessed the technical and economic viability of installing a grid connected solar pumping system for irrigation at selected GIDA schemes in the southern part of Ghana.
  - Technically, solar grid connected PV systems can be installed to meet the irrigation water requirements of each of the schemes studied.
  - However, based on the outstanding debt, initial capital cost of the PV system and payback period, Dawhenya Irrigation Scheme is recommended as the most favourable scheme to invest in.

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# Thank you!!!!!


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