SPECIAL ENERGY SEMINAR SERIES

Potential of distributed grid-connected solar PV for rural electrification in Africa

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PRESENTATION OUTLINE

- Project Background
- Equipment and Installations
- Work Done
- Results
- Conclusions
- Way Forward
- Acknowledgement

PROJECT BACKGROUND

- **Duration**
  - 3 Year Project, March 2012 – March 2015
  - Request made for 1year extension

- **Implementing Partners**
  - TEC, KNUST
  - CERC, University of Botswana
  - IIM, Europa Universität Flensburg

PROJECT BACKGROUND

- **Target Groups**
  - Technical staff of the public electric power utilities
  - Independent power producers (IPPs)
  - National policy and regulatory agencies
- **Beneficiaries**
  - Electricity end-users in rural communities
  - Public/private-sector institutions and
  - Commercial establishments in rural areas of Africa

PROJECT SITES

… SITE SELECTION

- Electrical system considerations
- Solar resource considerations
- Socio-economic, administrative, and related considerations

PROJECT SITES

… SITE SELECTION

Electrical System Considerations

- Savings from transmission losses
- Proximity to load centers (if majority of generated solar power not to be consumed in the community)
- Capability of existing system infrastructure (power lines, transformers, etc.) to absorb the power generated
- Potential to improve system's reliability by solving low voltage problems
- Significance of 30kWp injection at the community - to bring out expected scenarios for analysis

PROJECT SITES

… SITE SELECTION

Solar Resource and related Considerations

- Solar irradiation levels
- Appropriate roof space for mounting solar panels taking into consideration –

  i) appropriate orientation and tilt
  ii) immunity from shadows

PROJECT SITES

… SITE SELECTION

Socio-economic, administrative, and related factors

- Community rural in nature
- Adequate administrative and social structures to support the project and ensure sustainability
- Perceived immunity from theft, vandalism, etc.
- Immunity from thunder and lightning
- Perceived community support

PROJECT SITES

… SELECTED SITE IN GHANA

Walewale, Ghana

Government Hospital- Laundry

District Assembly

Catholic mission Hospital

Moon light Lodge

NED Office

District Police Office

District Fire Service

PROJECT SITES

… SELECTED SITE IN BOTSWANA

Mokolodi Village, Botswana

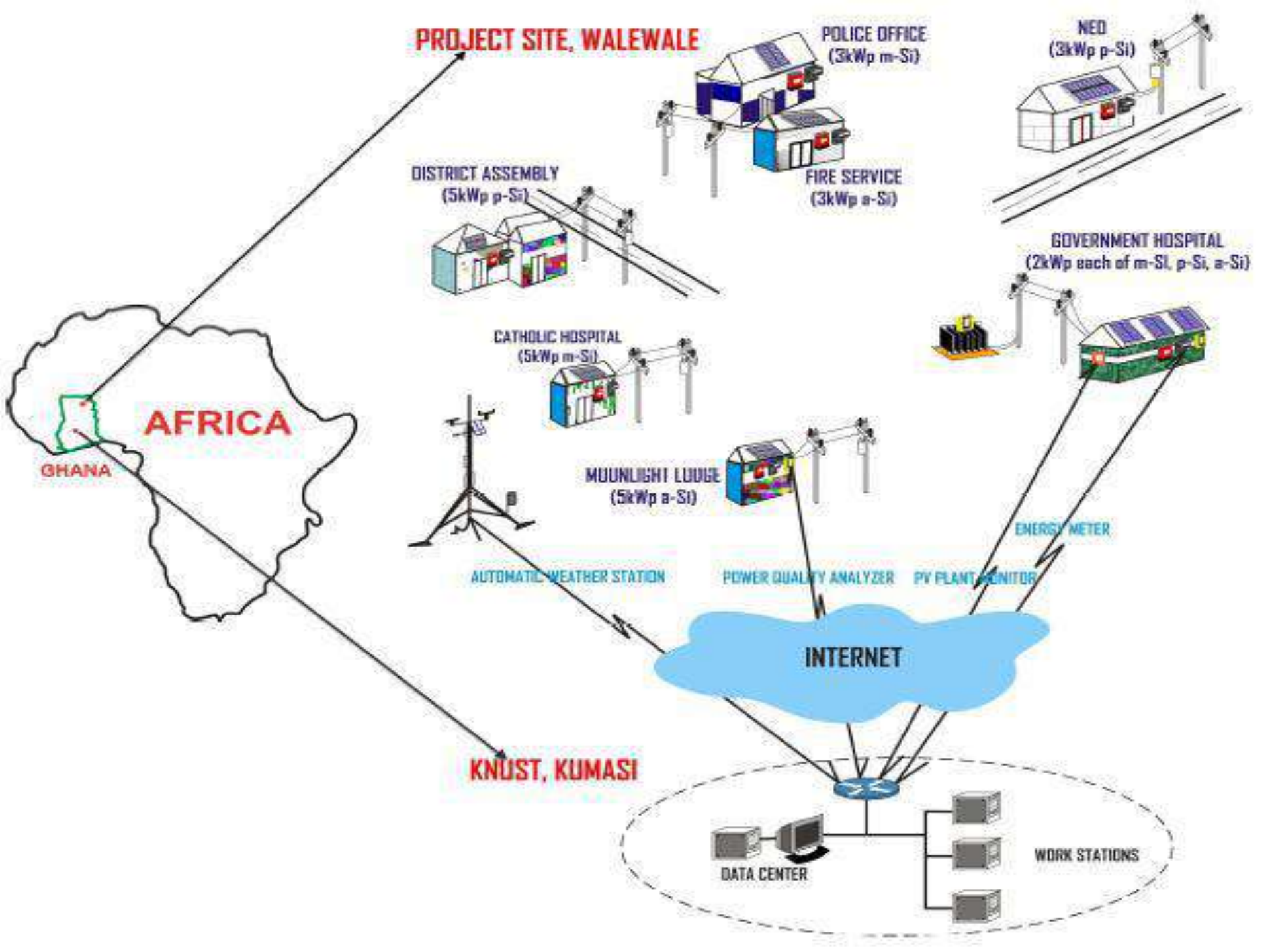
Hospital

Village Development Community(VDC) Building

EQUIPMENT AND INSTALLATIONS

Experiment set up consists of …

- **30kWp solar PV system** - 2kWp, 3kWp and 5kWp each of monocrystalline silicon(m-Si), polycrystalline silicon (p-Si), and amorphous silicon(a-Si) units,
- Plant Monitoring Equipment for all PV sites
- Automatic Weather Station (temperature, radiation, dust, wind speed, humidity, pressure, etc.)
- Power Quality Analyzers (8)
- Programmable Energy Meters (at all PV sites) and
- Data Center


PROJECT SITE, WALEWALE
POLICE OFFICE
(3kWp m-Si)
NEO
(3kWp p-Si)
DISTRICT ASSEMBLY
(5kWp p-Si)
FIRE SERVICE
(3kWp a-Si)
GOVERNMENT HOSPITAL
(2kWp each of m-Si, p-Si, a-Si)
CATHOLIC HOSPITAL
(5kWp m-Si)
AFRICA
GHANA
MOONLIGHT LODGE
(5kWp a-Si)
ENERGY METER
AUTOMATIC WEATHER STATION
POWER QUALITY ANALYZER
PV PLANT MONITOR
INTERNET
KNUST, KUMASI
DATA CENTER
WORK STATIONS

SITE AND EQUIPMENT DETAILS

No	Location	Solar PV Technology	Array Size	Grid-Connection	Transformer supply	Site Phase Supply	Transformer Sub-station name	Inverter type	Monitoring Equipment to be installed
1	Government Hospital	p-Si, m-Si, a-Si	2kWp for each	FIT	3-phase	3-phase	Hospital		PQA, energy meter, PME
2	District Assembly	p-Si	5kWp	FIT	Single phase	Single phase	Forestry	Reactive power control	PQA, energy meter, PME
3	Catholic Hospital	m-Si	5kWp	FIT	Single phase	Single phase	Ministries	Reactive power control	PQA, energy meter, PME
4	Moon Light Lodge	a-Si	5kWp	NM	Single phase	Single phase	DCE Residence Sub-station		Energy meter, PME
5	NED office	p-Si	3kWp	FIT	3-phase	3-phase	NED		PQA, energy meter, PME
6	District Police Office	m-Si	3kWp	NM	Single phase	Single phase	Forestry		Energy meter, PME
7	District Fire Service	a-Si	3kWp	NM	3-phase	Single phase	Kperiga		Energy meter, PME

WORK DONE

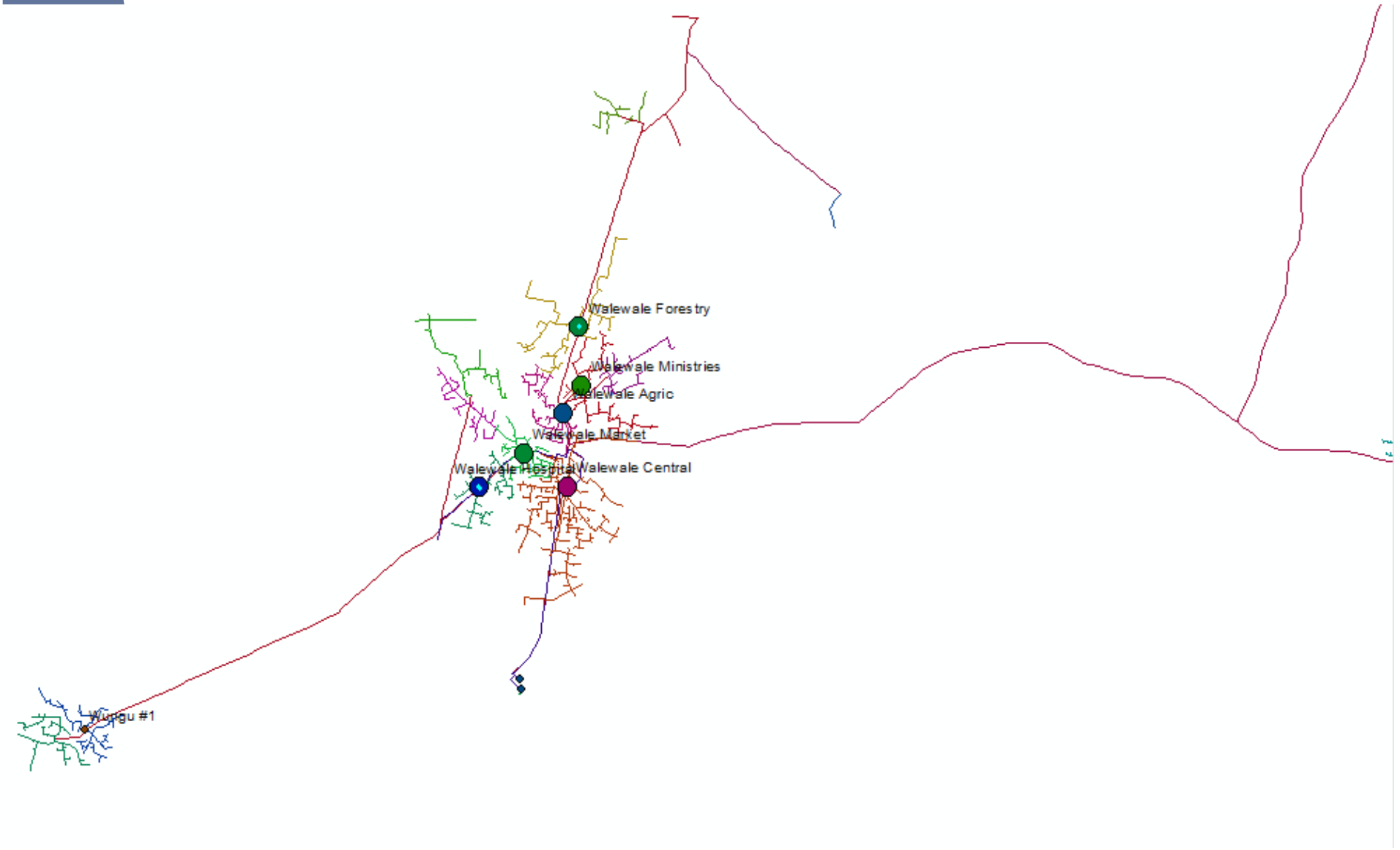
- Solar resource assessment
- PV yield estimation – using RETScreen
- Financial analysis --using RETScreen
  - feed-in tariff : US$0.21/kWh, discount rate:10%, project life: 10years and PV system cost varied from US$4.00/Wp to US$1.00/Wp.
- Network modelling
- Simulations in Paladin
- Measurement of Power Quality(PQ) Data
- Automatic Weather Station(AWS) installation and configuration

NETWORK MODELLING

- GIS map of Walewale LV network obtained from NEDCo
- Team collaborated with NEDCo to obtain network data
- LV network subsequently modelled

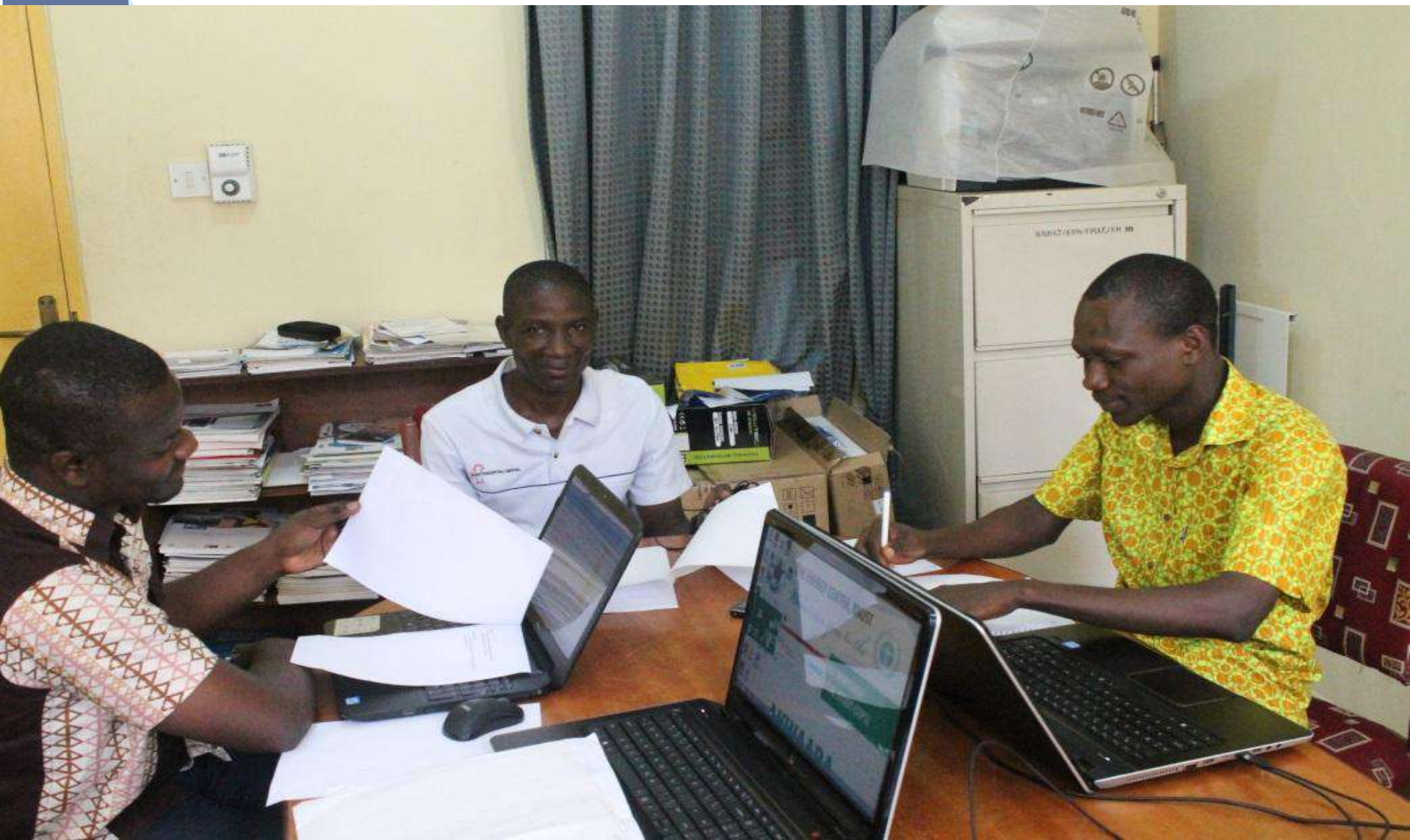
NETWORK MODELLING

GIS MAP OF WALEWALE



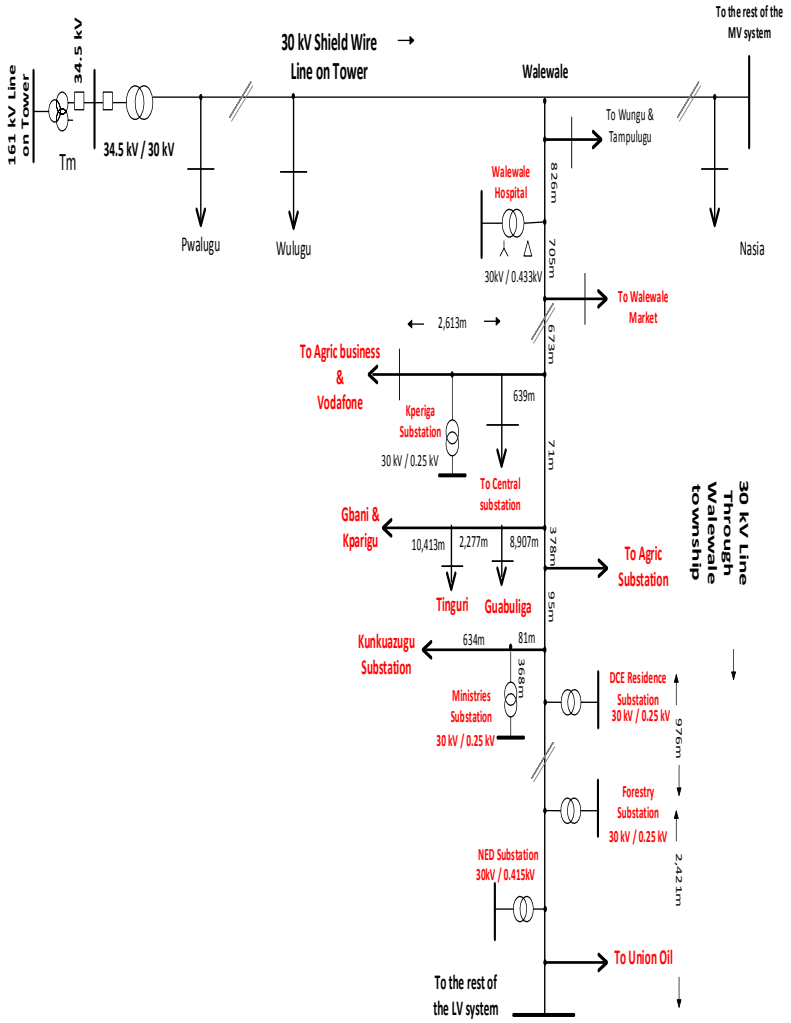
NETWORK MODELLING

…MEETING WITH NEDCO ENGINEER



NETWORK MODELLING

WALEWALE LV NETWORK DIAGRAM



MEASUREMENT OF POWER QUALITY

- PQ is being measured to know condition of the grid before PV integration.

- Measurement locations
  - A substation transformer
  - Selected installation sites

MEASUREMENT OF POWER QUALITY

…PQ ANALYZER BEING MOUNTED ON TRANSFORMER

MEASUREMENT OF POWER QUALITY

...PQ ANALYZER BEING MOUNTED AT A CUSTOMER RESIDENCE

MEASUREMENT OF POWER QUALITY

…RETRIEVAL OF DATA FROM PQ ANALYSER

AWS INSTALLATION

- An Automatic Weather Station has been installed at the West Mamprusi District Hospital, Walewale.

- Stages undergone before completion;
  - Assemblage of system components
  - Training on Operation and Maintenance
  - Installation
  - System Configuration

AWS INSTALLATION

TRAINING SESSION WITH SUTRON SYSTEM INTEGRATION ENGINEER

AWS INSTALLATION

. . . *FENCE ERECTION*

AWS INSTALLATION

…MOUNTING THE TOWER

AWS INSTALLATION

…AWS COMPLETELY INSTALLED

AWS INSTALLATION

SYSTEM CONFIGURATION

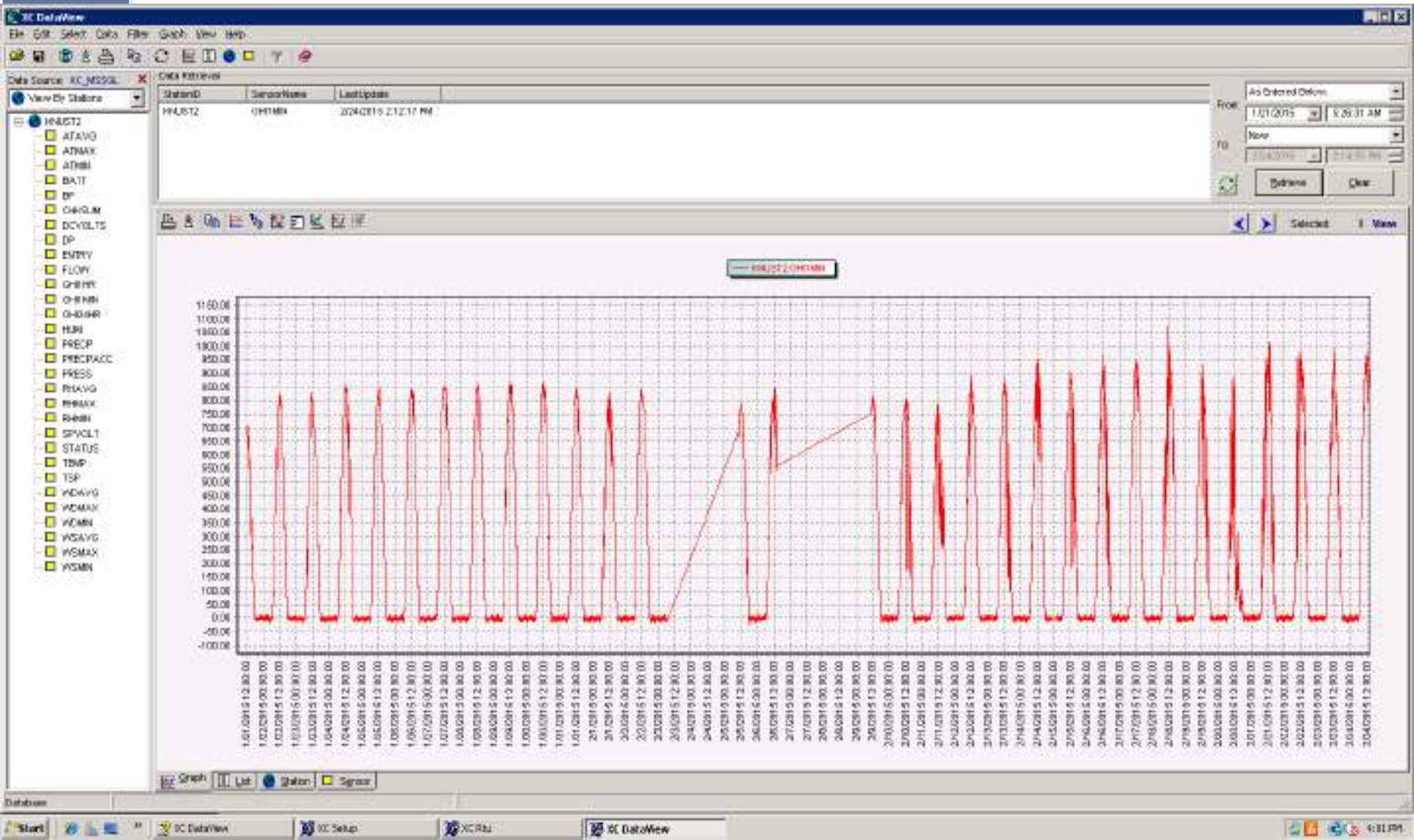
- X-Connect software installed on server at KNUST
- AWS configured to automatically send data to the server

AWS INSTALLATION

AWS CONFIGURED TO COMMUNICATE WITH X-CONNECT

AWS INSTALLATION

X-CONNECT INTERFACE

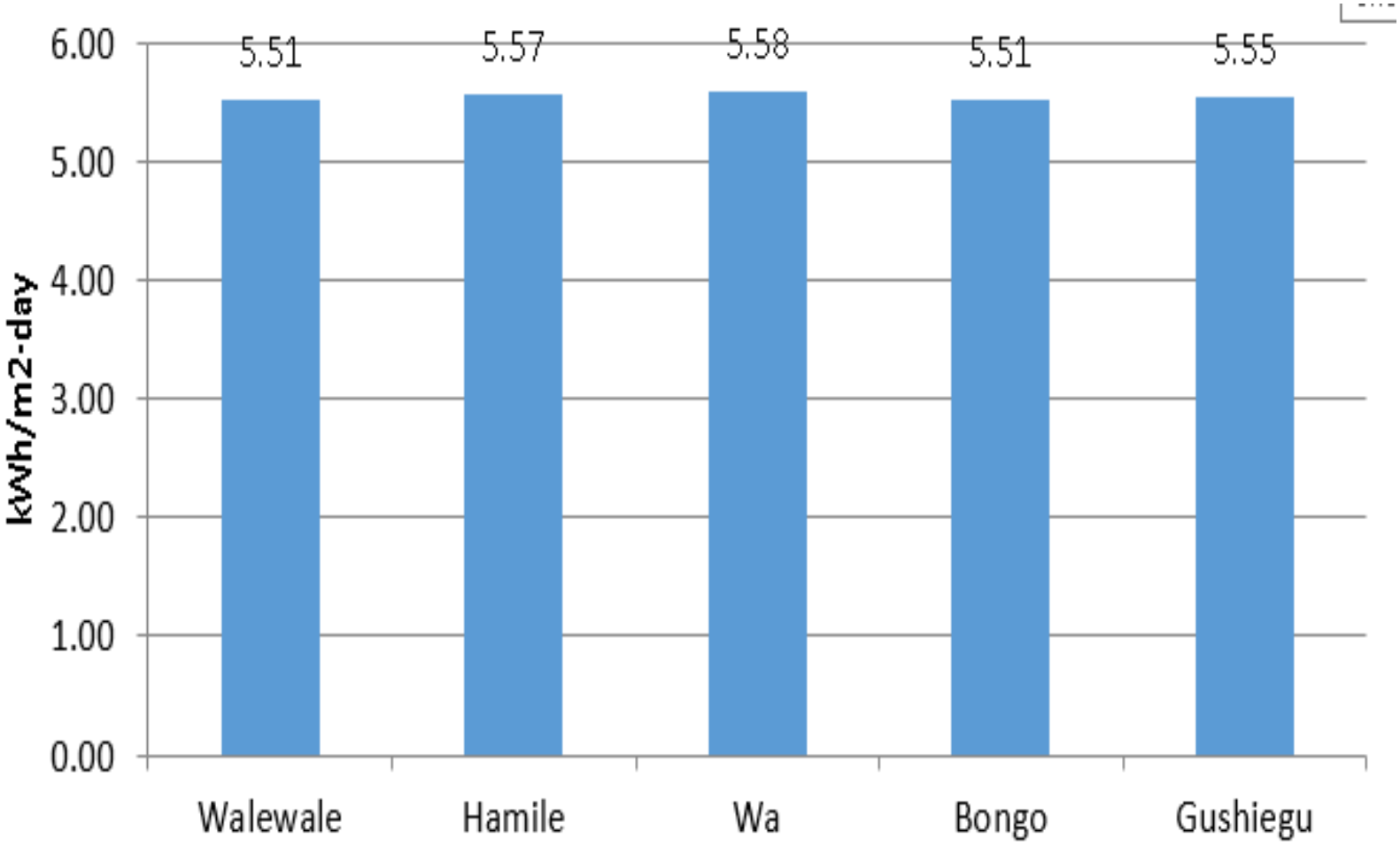


RESULTS

- Solar resource assessment
- PV yield estimation
- Financial analysis
- Paladin Simulations

RESULTS

… SOLAR RESOURCE ASSESSMENT



RESULTS

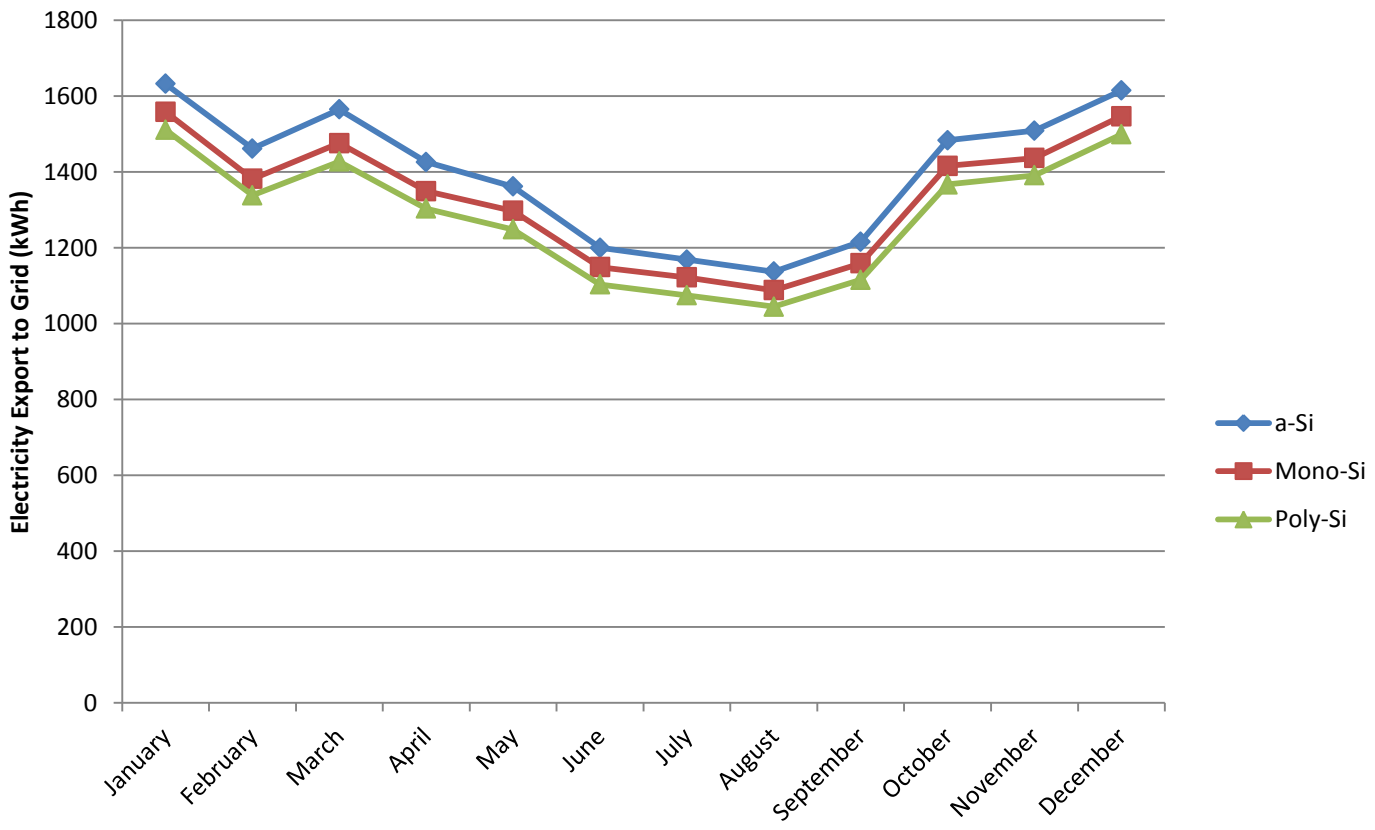
… ESTIMATED PV YIELD

- Annual Yield:
  - 10kWp a-Si: 16,775kWh
  - 10kWp m-Si: 15,980kWh
  - 10kWp p-Si: 15,425kWh

  - Total (30kWp): **48,180kWh**

RESULTS

… YEARLY PV PERFORMANCE



RESULTS

… FINANCIAL ANALYSIS

Cost of System (US$/Wp)	NPV (US$)	Simple Payback (Years)
4	-57,830	11.86
3	-27,830	8.9
2	2,170	5.93
1	32,170	2.97

- Annual total revenue: **US$ 10,117.84**

RESULTS

… ENVIRONMENTAL BENEFITS

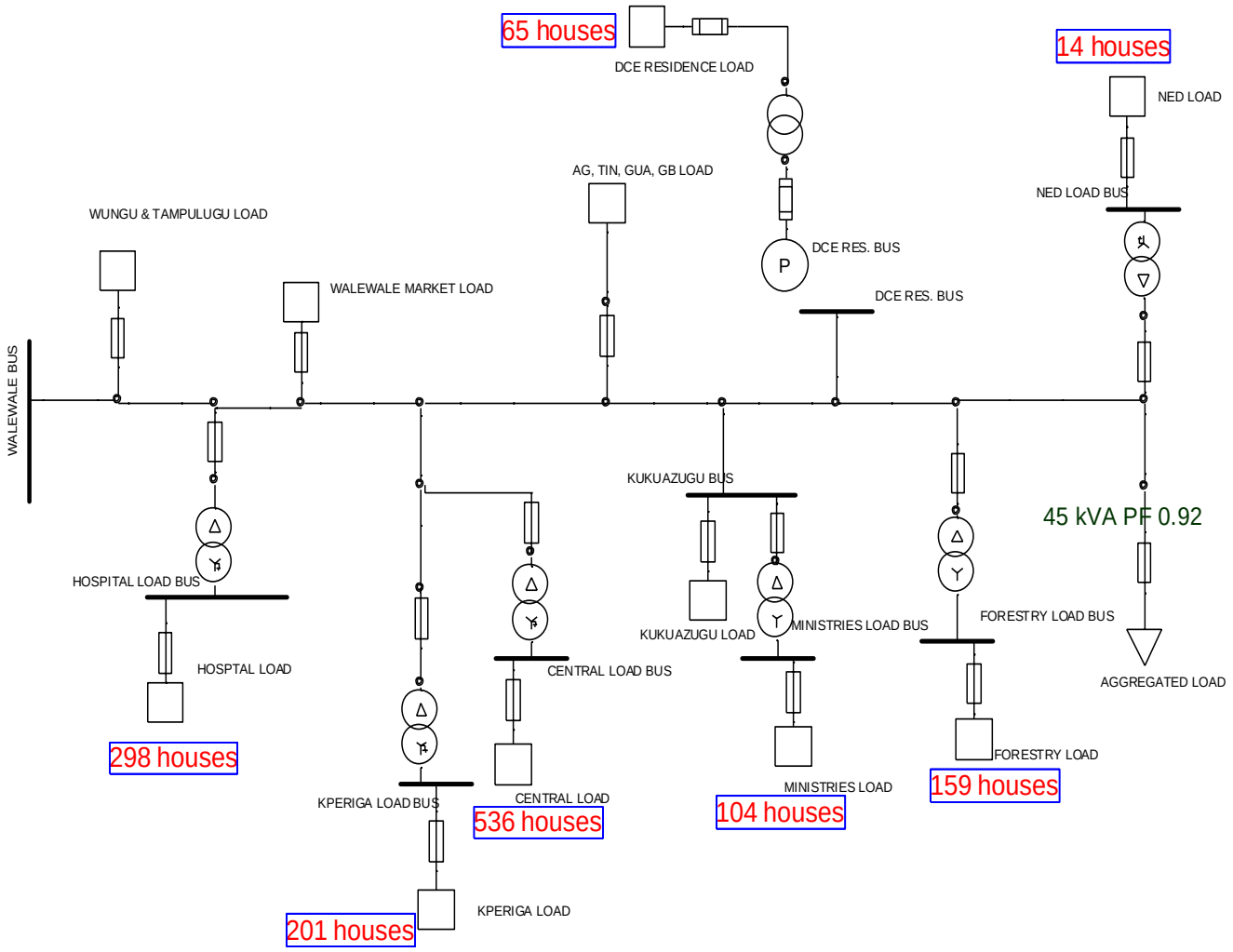
- Annual GHG savings:

33tCO_2

RESULTS

… *PALADIN SIMULATIONS*

Single-line diagram of Walewale LV distribution network



RESULTS

. . . PALADIN SIMULATIONS

PV generation at increasing penetration level for each location

PV Location	Base case (kWp)	30% PV	50% PV	100% PV	150% PV	200% PV	250% PV	300% PV	350% PV	400% PV
Hospital	6	47.8	79.7	159.4	239.1	318.8	398.6	478	558	637.7
District Assembly	5	39.9	66.4	132.9	199.3	265.7	332.1	399	465	531.4
Catholic Hospital	5	39.9	66.4	132.9	199.3	265.7	332.1	399	465	531.4
Residential	5	39.9	66.4	132.9	199.3	265.7	332.1	399	465	531.4
NEDCo Office	3	23.9	39.9	79.7	119.6	159.4	199.3	239	279	318.8
District Police Office	3	23.9	39.9	79.7	119.6	159.4	199.3	239	279	318.8
District Fire Service	3	23.9	39.9	79.7	119.6	159.4	199.3	239	279	318.8
Total (kWp)	**30**	**239.1**	**398.6**	**797.1**	**1195.7**	**1594.2**	**1992.8**	**2391**	**2789.9**	**3188.4**

RESULTS

. . . PALADIN SIMULATIONS

Points on the network where low voltages occur

- NB: The allowable limits for voltage drop according to **ANSI C84.1 Electric Power System and Equipment – Voltage Ranges is** ±5%.

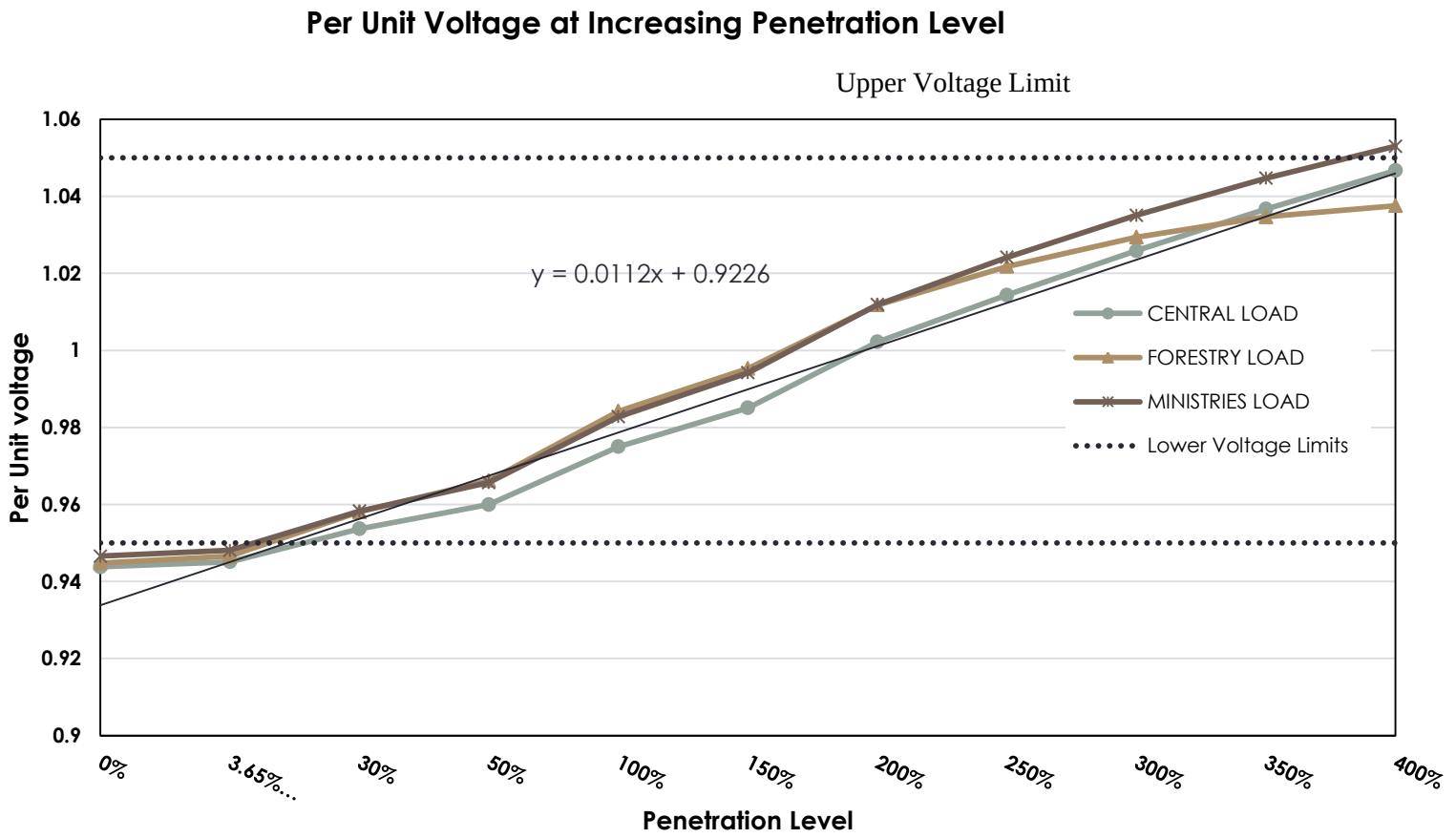
Location	% Voltage drop	Status/ Violation
KukuazuguLoad	4.28	Within Limits
KukuazuguBus	4.28	Within Limits
Kperiga Load Bus	4.55	Within Limits
KperigaLoad	4.56	Within Limits
HosptalLoad	4.87	Within Limits
Hospital Load Bus	4.84	Within Limits
Dce Res. Bus	4.28	Within Limits
BolgaBus	1.18	Within Limits
Aggregated Load	4.3	Within Limits
Ag, Tin, Gua, Gb Load	4.41	Within Limits
Central Load	5.62	Under Voltage
Central Load Bus	5.55	Under Voltage
Forestry Load	5.52	Under Voltage
Forestry Load Bus	5.48	Under Voltage
Ministries Load	5.34	Under Voltage
Ministries Load Bus	5.31	Under Voltage
NasiaBus	3.91	Within Limits
NasiaLoad	3.92	Within Limits
Ned Load	4.58	Within Limits
Ned Load Bus	4.58	Within Limits
Walewale Bus	3.8	Within Limits
Walewale Market Load	4.23	Within Limits
WuluguBus	3.2	Within Limits
WuluguLoad	3.2	Within Limits
Wungu&TampuluguLoad	3.81	Within Limits

RESULTS

… PALADIN SIMULATIONS

Per Unit Voltage at Increasing Penetration Level

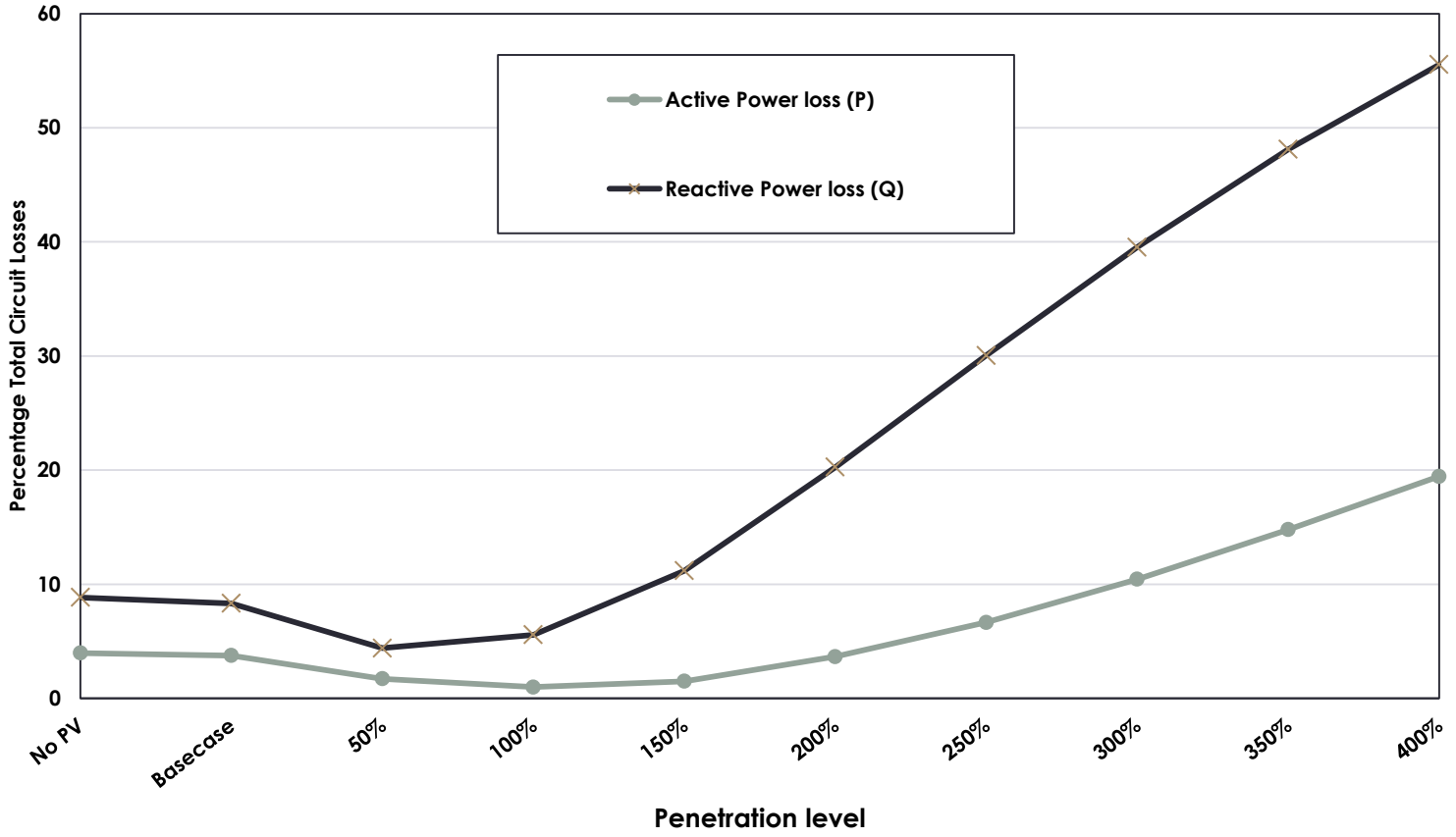
- Service point voltage range should not fall outside the limits of 1.05 p.u and 0.95 p.u (***ANSI C84.1***)



RESULTS

… PALADIN SIMULATIONS

Percentage Power system losses at increasing PV penetration



RESULTS

... PALADIN SIMULATIONS

Branch losses at increasing PV penetration

Branch Name		Active Power losses (W)			Percentage change in losses
From	To	No PV (0%)	50% PV	100% PV	No PV to 100% PV
Bolga	Wulugu	22271.25	9403.56	3920.24	-82.4
Wulugu	Walewale	6406.07	2611.02	1085.2	-83.1
Walewale	Nasia	147.02	143.26	139.9	-4.8
Walewale bus	Wungu	104.22	37.14	16.57	-84.1
Wungu	Hospital	3409.74	1155.12	548.38	-83.9
Hospital	Market	289.28	102.27	47.03	-83.7
Market	Central	228.38	71.99	39.53	-82.7
Central	Incomer	61.37	30.49	13.4	-78.2
Central	Kperiga	5.49	1.08	1.97	-64.1
Central	Ag, Tin	33.38	6.35	14.66	-56.1
Ag, Tin	Gbani	166.8	161.71	157.17	-5.8
Ag, Tin	Kukuazugu	2.78	0.58	5.53	98.9
DCE	Forestry	2.37	0.53	5.08	114.3

CONCLUSIONS

- There is good solar resource in northern Ghana
- a-Si panels produce the greatest yield in Walewale
- PV integration results in reduction of system losses up to about 100% penetration and thereafter, in increasing losses.
- PV integration helps improve the local voltage profile and can be used to solve under-voltage situation within distribution networks.
- For Walewale, ideal locations for using PV to improve voltage profile are **Central Load, Forestry Load and Ministries Load**.
- If scaled up, project has potential for GHG mitigation
- Distributed solar-PV for rural electrification in Ghana (and in Africa-to be determined), if solar PV system costs fall below US$ 3/Wp

WAY FORWARD

- PV installations
- Measurement of PV yield, inverter performance, etc.
- Analysis of Data
- Writing of Grid Codes
- Policy Recommendations

ACKNOWLEDGEMENT

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THE END

Thank You!