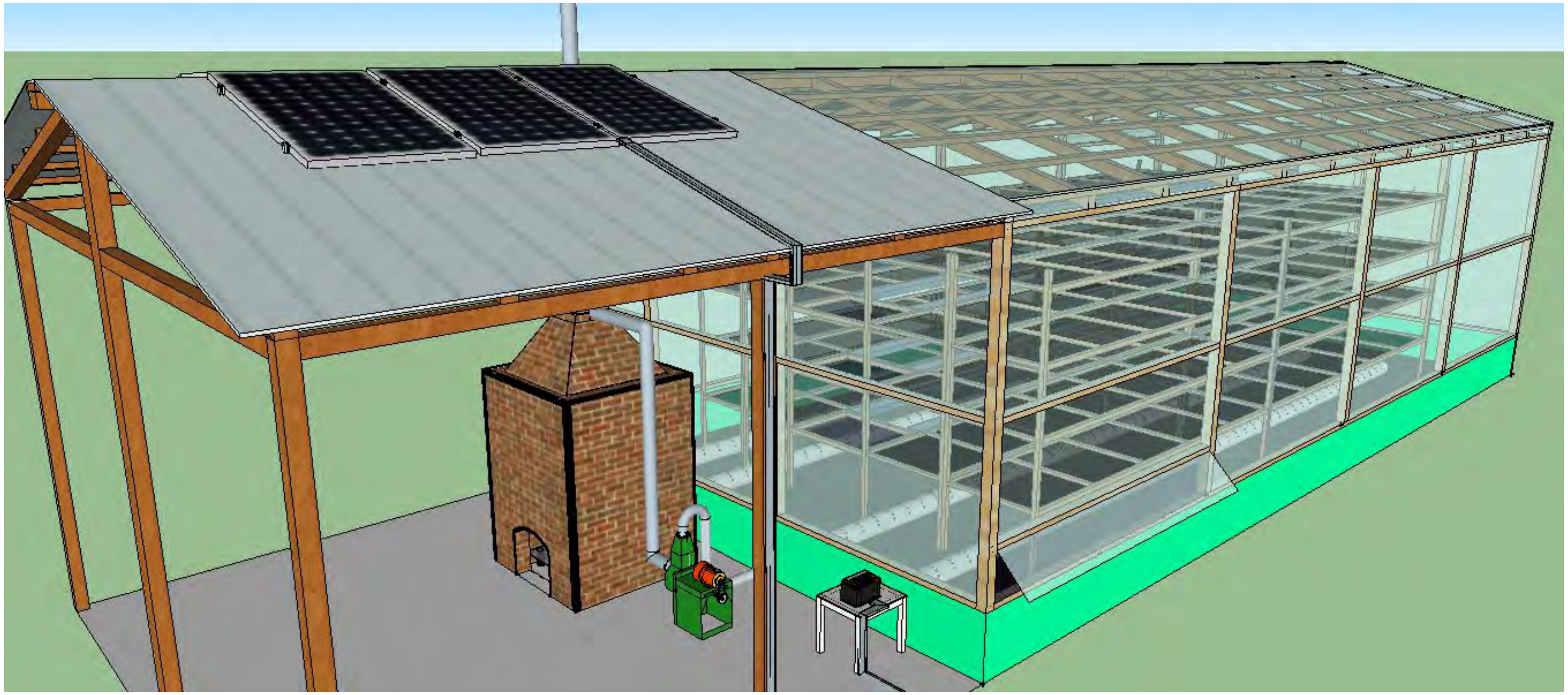
Energy Efficient Rural Food Processing Utilising Renewable Energy to Improve Rural Livelihoods(RE4Food) in Ghana



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Outline of presentation

- Background
- Project Objectives
- Activities Undertaken so far
- Outstanding Activities
- Concluding Remarks

1. Background

- Maize is a staple crop grown in almost all parts of the country and contributes significantly to economic development
  - Food (it is a food security crop)
  - Income (for actors in the value chain)
  - Input for major industries in the country (Nestle, breweries, feed mills etc)

- Field and post-harvest losses identified as the most significant constraints limiting maize utilisation in Ghana
  - Inappropriate post harvest practices

- Energy is required to preserve food, reduce post-harvest losses to extend availability of food over a longer period.

Project aim and objectives

- The project aims at contributing to the resolution of the challenges in the maize sector by
  - *Providing research to support rural community business models for low and renewable energy input to optimise food processing which minimise losses and waste in maize food processing.*

    - Investigate the opportunities and barriers to the use of renewable energy for maize food processing at the rural level.

    - Deliver focused support to stakeholders through a network facilitating engagement, dissemination and knowledge transfer to reduce postharvest losses and energy demand for maize processing.

    - Explore opportunities to improve rural livelihoods by reducing post-harvest losses and value addition through processing technologies and practices which can be de-centrally applied by taking advantage of renewable energy sources in a cost-effective way.

Activities Undertaken so far

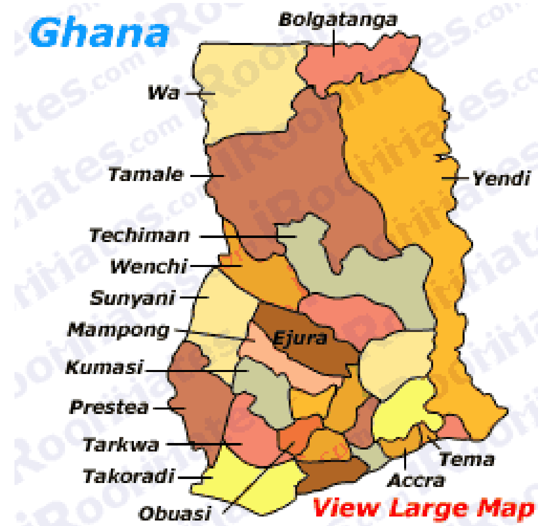
1. Reconnaissance & Baseline surveys

- Investigate practices of maize farmers and traders that contributes to losses

- Study was conducted in Ejura Sekyeredumase Municipality in the Ashanti Region.

- Maize farming areas in the Municipality were put into 3 cluster zones based on geographical or ecological location of farm
  - One hundred and fifty (150) maize farmers were selected across 134 communities in the three cluster zones for the survey

- Two major markets were also used for the surveyed
  - Ejura market
  - Agbobloshie market



A. Maize farming activities

- **Farm size-** Majority of farmers (62%) in study area are smallholder farmers with farm sizes about 2 ha (5 acres).
- **Planting material-** Majority of farmers (82%) use their own seed stock as planting material
- **Fertiliser application-** Majority (89%) relied solely on chemical fertiliser (NPK)

B. Harvesting and drying practices

- **Minor season –** 93% practice delay harvesting to allow for field drying
- **Major season** – Majority of farmers harvest early to engage the land for other purposes. Drying is normally done in the open though it coincides with the raining season.

C. Assessing dryness of maize before harvest

- **Dried maize before harvest–** Assessed through
  - Biting maize with teeth (confirmed by 80% of farmers)
  - Drooping of cobs and dried tassels (69%)
  - Only 31% of the farmer's knew the maturity period of the type of maize planted

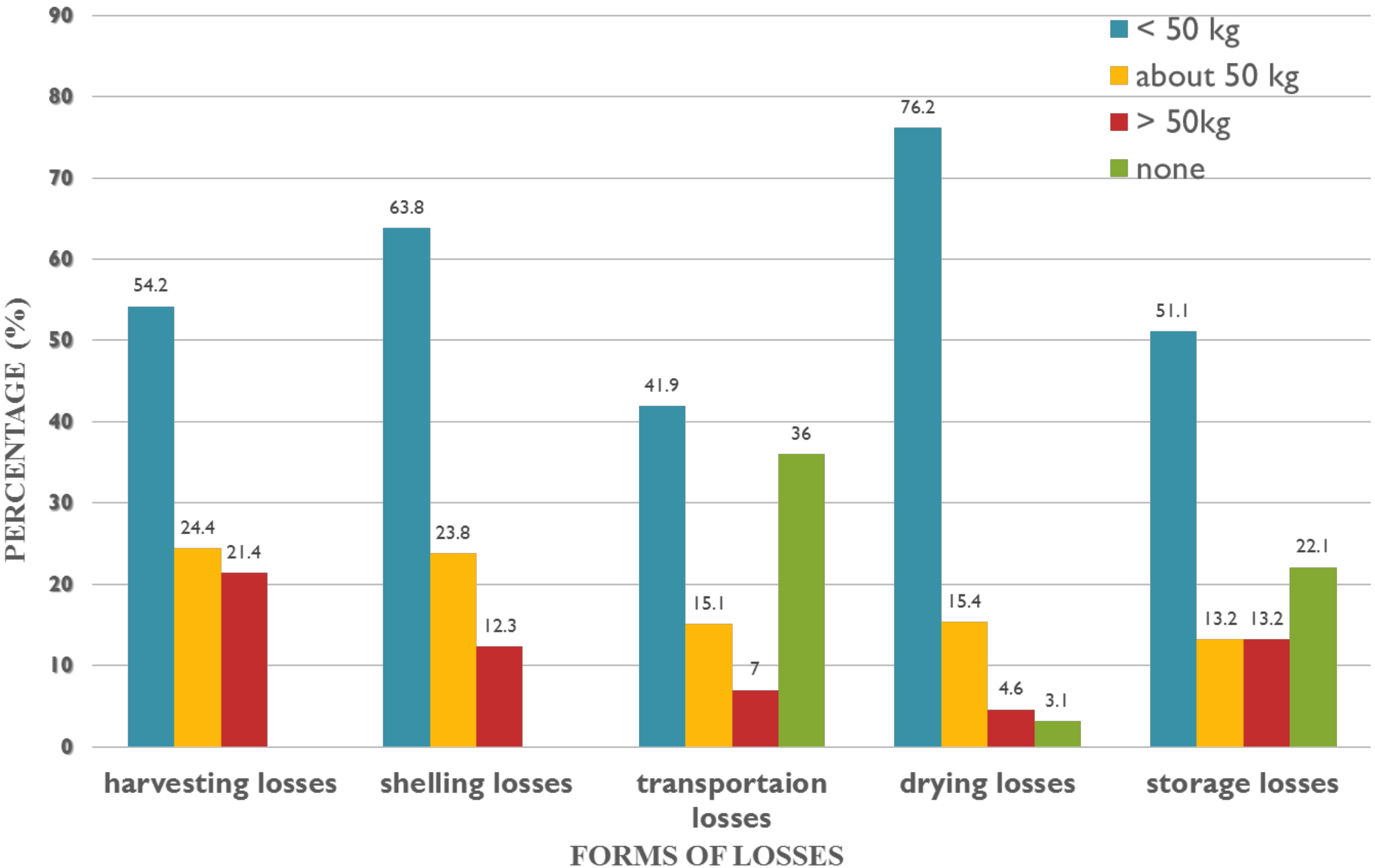
D. Maize shelling practices

- Majority of farmers (97%) mostly use a mechanised mobile maize sheller

E. Storage practices

- Majority of farmers (64%) sell their maize immediately after harvest during the minor season
- Storage on cobs is a common practice during the major season- confirmed by 36% of farmers

Key areas losses occur along the maize value chain



MAIZE LOSSES EXPERIENCED ALONG THE VALUE CHAIN FROM THE FARMERS' PERSPECTIVE

Activities Undertaken so far

2. Field loss assessment

- Quantitative and qualitative maize loss assessment in major and minor season of 2013.
- Key areas considered for quantitative loss assessment were
  - Harvesting
  - Shelling
  - Drying
- Qualitative loss assessment was done on aflatoxin contamination

Harvest loss assessment

- Estimation of maize plant population and yield

Farm	Avg. Plant population for 100m^2	Farm size(m^2)	Plant population	Weight of shelled maize for 100m^2 (kg)	Total weight of maize (kg)	Expected Numb. Of bags	Actual Numb. Of bags
1	230	15,045	34,604	15.33	2,306.90	14.56	10
2	418	10,584	44,241	21.67	2,293.20	14.47	9
3	378	18,080	68,342	8.89	1,607.11	10.13	8

Harvest loss assessment

- **Harvest loss due to unpicked maize on field**

Farm	Weight of shelled maize for 100m^2 (kg)	Estimated average weight of unpicked maize grains for 100m^2 (kg)	Estimated total weight of unpicked maize grains (kg)	Expected total weight of maize (kg)	Harvest loss (%)
1	15.33	0.21	31.59	2,306.90	1.37
2	21.67	0.48	50.80	2,293.20	2.22
3	8.89	0.19	34.35	1,607.11	2.14
Average					1.91

- The average loss due to unharvest/unpicked maize grains was estimated to be **1.91%**

Shelling loss assessment

Farm	Loss due to unshelled maize on cobs(%)	Scattering losses (%)
1	5.32	0.22
2	9.8	0.14
3	4.2	0.16
Average	**6.44**	**0.17**

- Total loss of **8.52%** translates into estimated maize food loss for the Municipality for the 2013 minor production season as **1,511** tons at a production figure of 17,729 tons.

Drying loss assessment

Sample	Weight before drying (kg)	Mc before drying (%)	Damage grains (kg)	Mc after drying (%)	Weight at 13% Mc	Loss (%)
1	280	17	35.6	13	273.4	13.3
2	560	18	55	14	540.2	10.3
3	1120	17.5	145	13.6	1087.1	13.6
Average						**12.4**

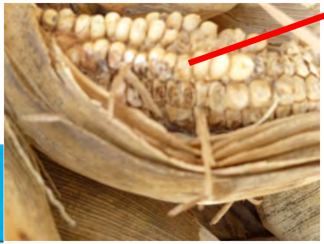
- Total loss of **12.4%** translates into estimated maize food loss of **1,727** tons at a production figure of 13,930 tons.

Aflatoxin contamination

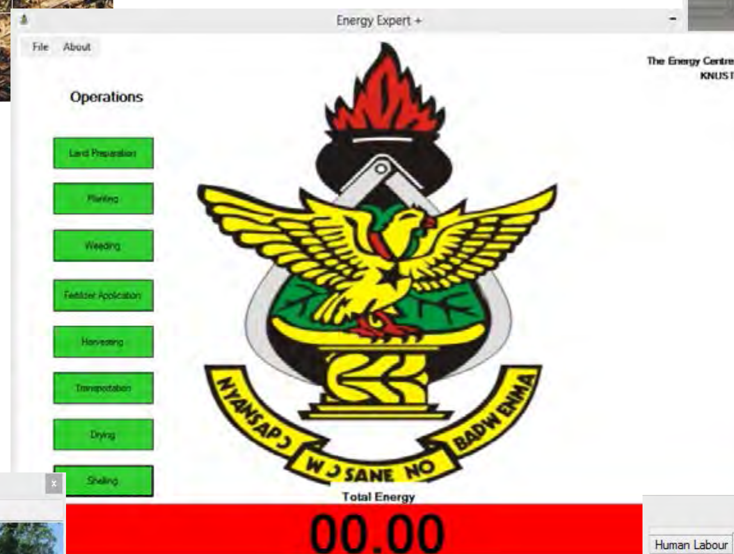
Sample ID	G2	G1	B2	B1	TOTAL
EJ1	19.132	<LOD	10.844	20.258	50.234
EJ2	10.698	18.863	15.196	25.345	70.102
EJ3	<LOD	<LOD	12.178	18.765	30.943
AG1	<LOD	Absent	23.564	653.916	677.48
AG2	<LOD	<LOD	10.498	91.25	101.748
AG3	26.302	1670.888	133.856	3000.896	4831.942

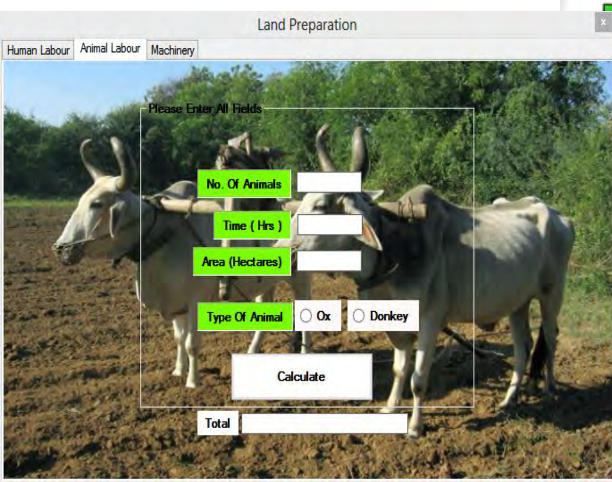
LOD= limit of detection (G2, G1= 1.5ng/g; B2, B1= 0.8ng/g). Maximum limit for safe consumption of aflatoxin contaminated maize is 20ng/g

Parameter	Farm	Ejura Market	Agbobloshie market
Moisture content (%)	<13	12.5 - 13.4	13.1 - 16.6
Weevil infestation	Absent	Low	High
Presence of mould	No	Yes	Yes
Aflatoxins present	Yes	Yes	Yes
Level of aflatoxins	<LOD	>LOD	>LOD

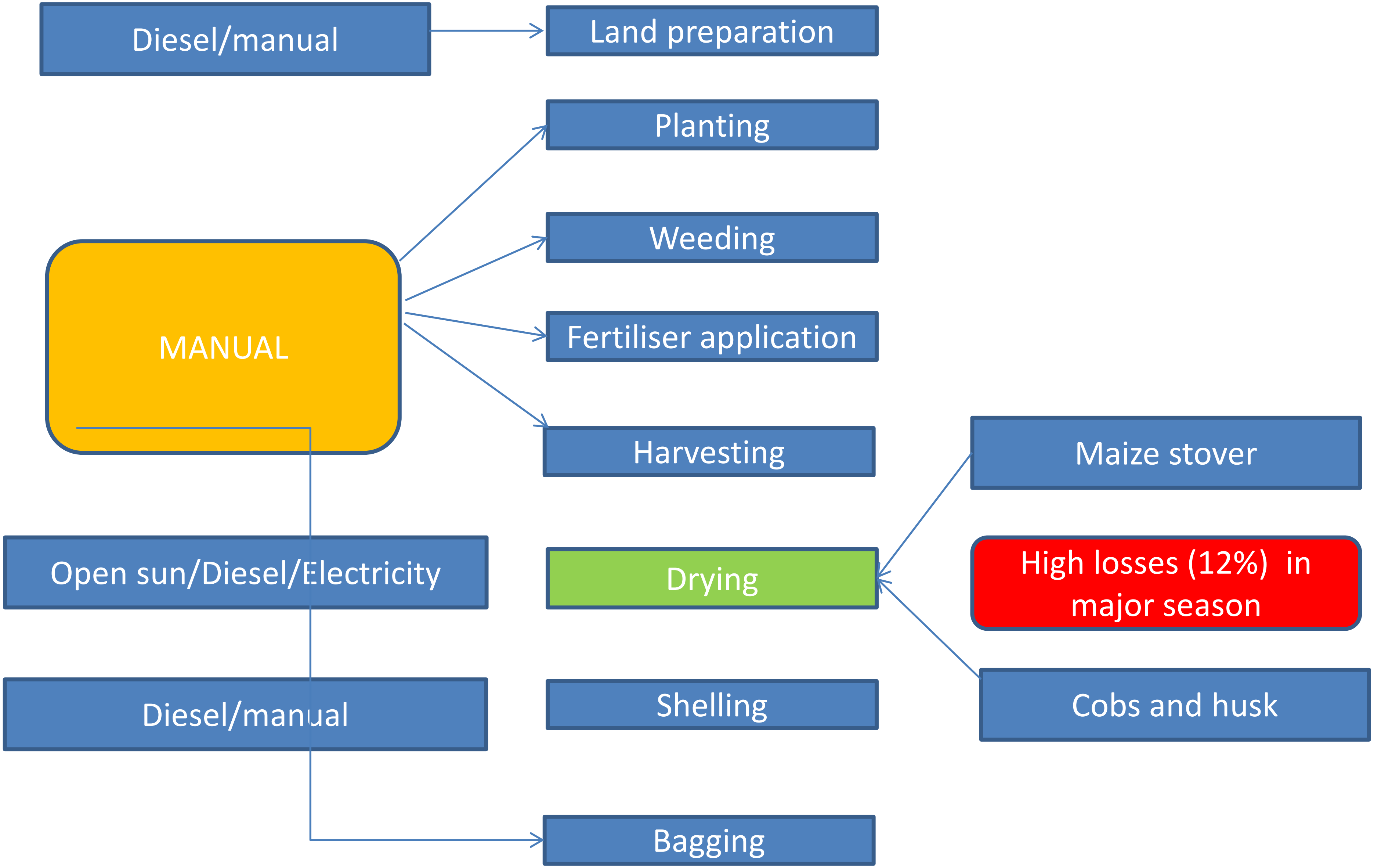


3. Assessment of energy demand for maize food production



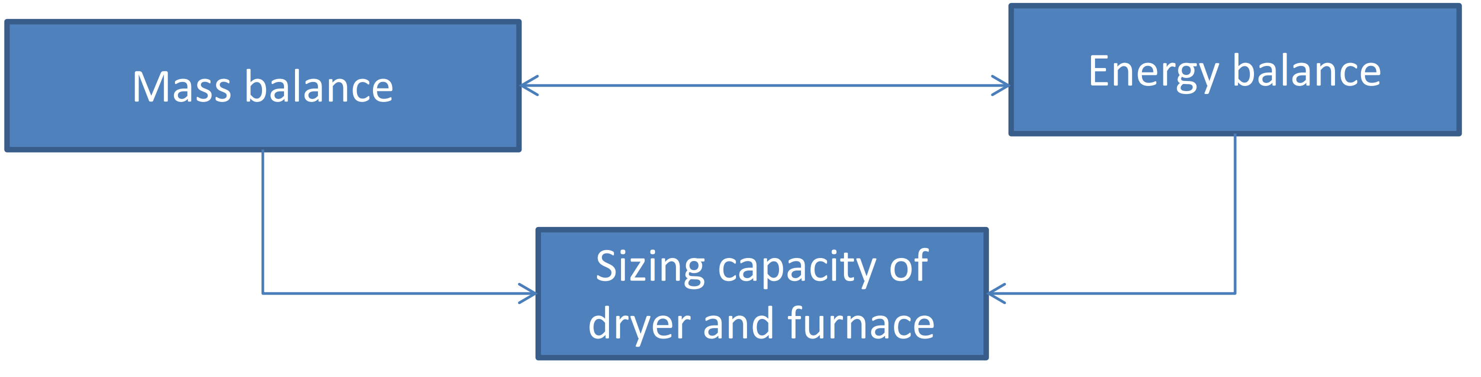


Assessment of potential areas along maize value chain for renewable energy (RE) integration

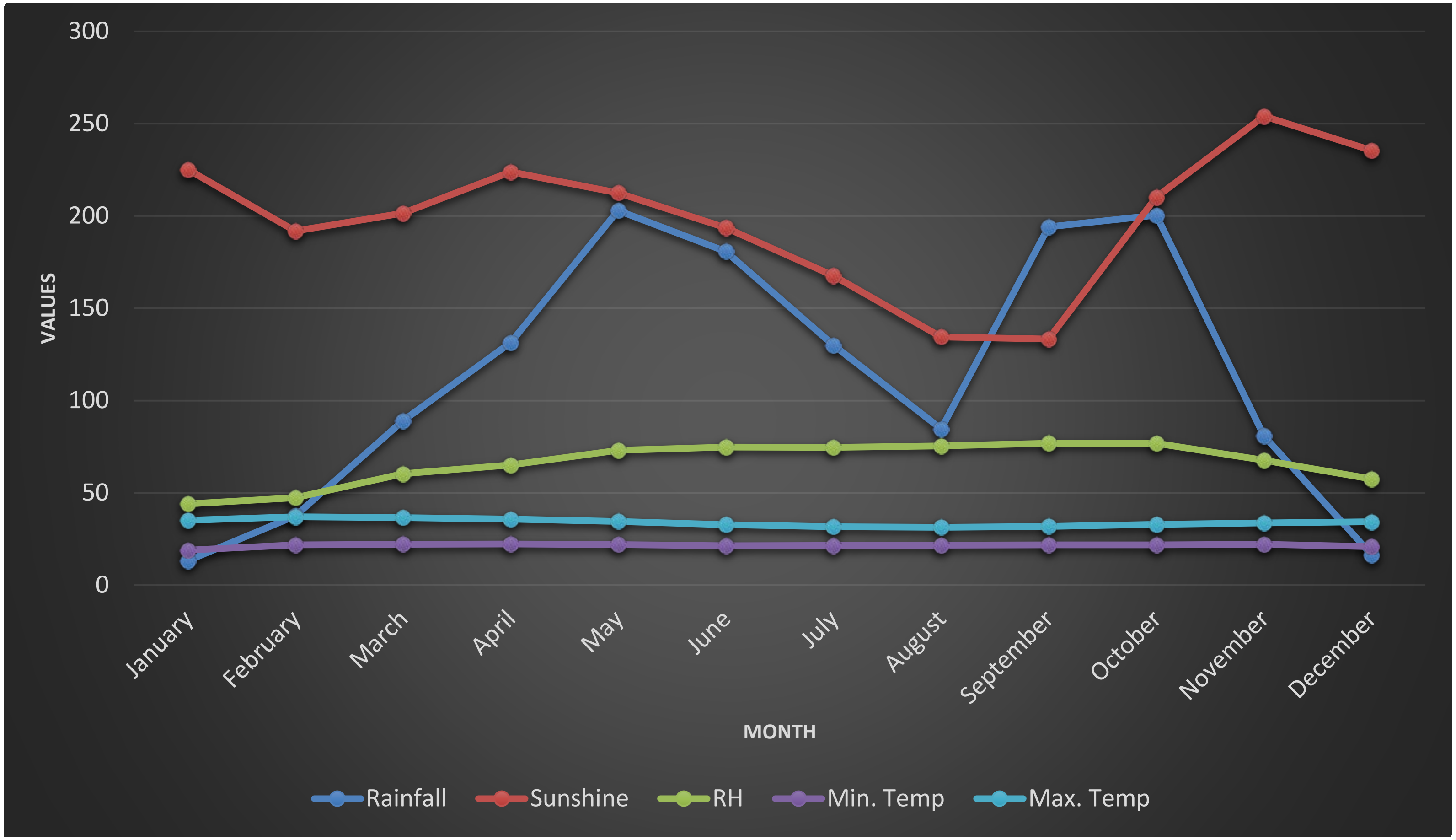


Integration of RE technology into maize drying process to increase quality, reduce losses and maximise use of maize cobs

- Technical parameters for design of RE technology
  - Weather condition assessment of study area
  - Availability of biomass (corn cobs)
  - Amount of maize to be dried, initial and final moisture contents
  - Ability to dry maize during humid periods of the year (Incorporation of biomass furnace as back-up thermal system)



Simulated weather condition of study area using 10 year period data (2004-2013)



Maximum temperature conditions : **31 -37 ^{o}C ,** **Sunshine hours: 133 – 256 h**
Relative Humidity: **44 – 77%**

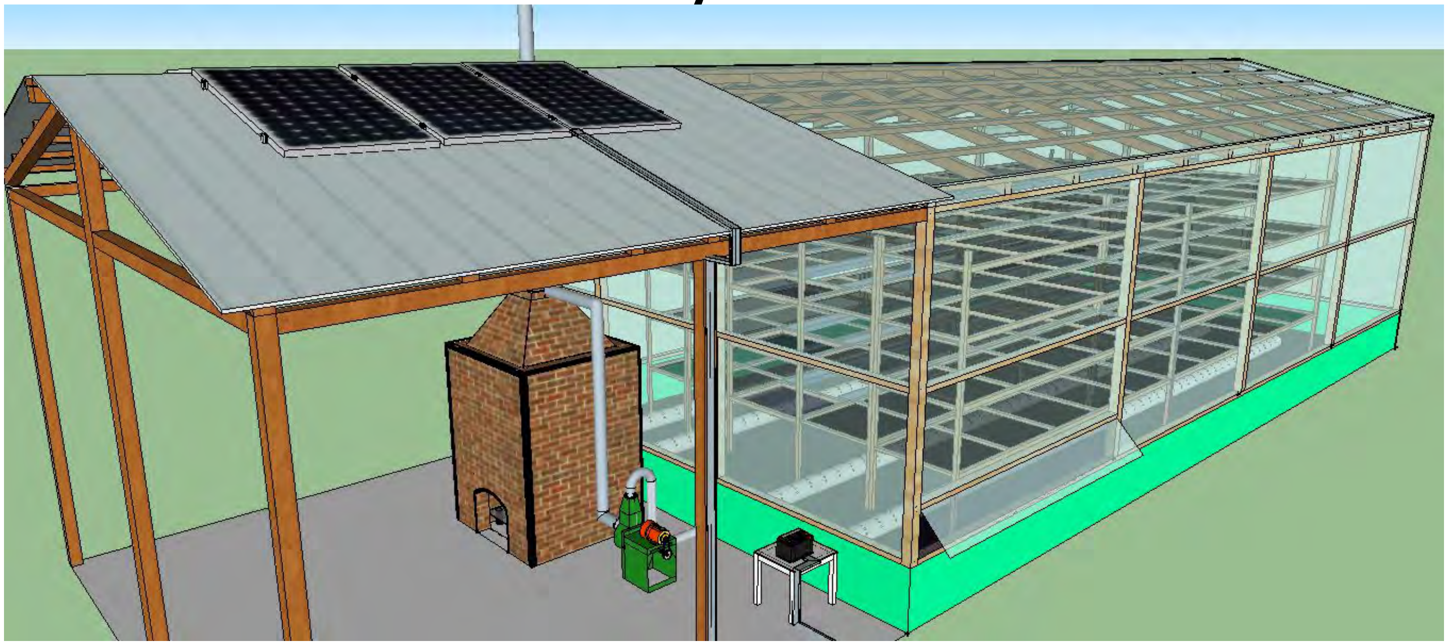
- Estimation of maize residues generated annually

Residue type	RPR	I ha farm/yr (tons)	2 ha farm/yr (tons)	Amount of residues/yr (tons) in the municipal
Maize stalk	2.68	3.16	6.32	63,751.84
Maize husk	0.2	0.24	0.47	4,757.60
Maize cob	0.25	0.30	0.59	5,947.00
Total residues		3.75	7.50	**74,456.44**

- Estimated amount of available crop residue was done using the residue to product ratio (RPR) and the maize yield in the municipality.

- This indicates that, maize residues are readily available for combustion

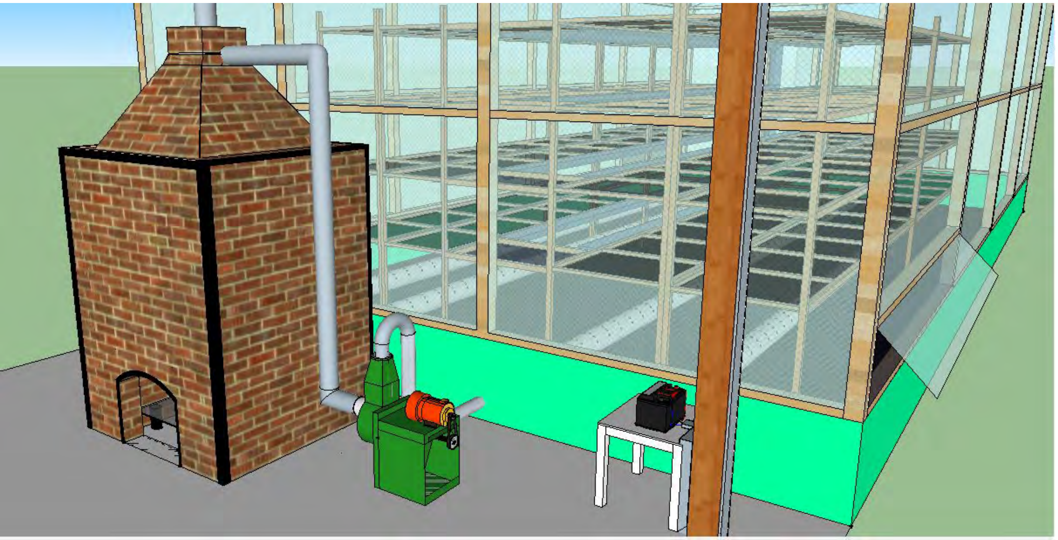
Developed RE technology-solar biomass maize dryer



- Dryer capacity: 3-5 tons/batch
- Expected drying period: 8 hours
- Initial MC of shelled maize: 20-25% MC_{wb}
- Final MC of shelled maize: 12-13%
- Ambient air condition: 22^{o}C; RH = 65%
- Drying temperature: 70^{o}C

- Estimated corncob consumption = 25kg/h
- Dryer specification: 13 × 8 × 3 m
- No of shelves = 120 @ 1.2 × 0.9 × 0.05 m

Solar biomass maize dryer



Water evaporated = 0.57 tons

5 tons shelled corn
22% (MC_{wb}) moisture

DRYER

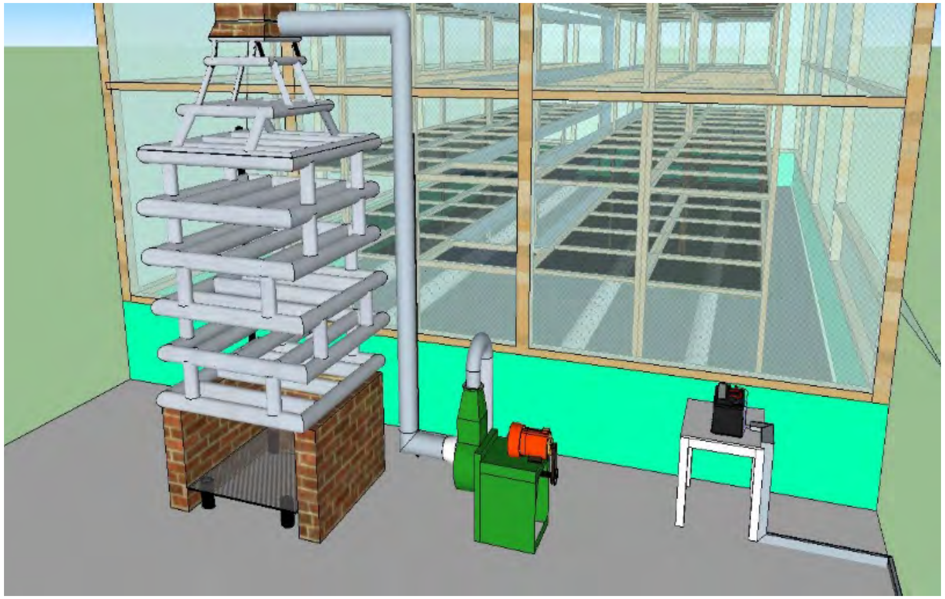
Dry shelled corn

3.9 tons shelled corn
+ 1.1 ton water

4.4 tons dried shelled @
12% (MC_{wb})

Corncob Furnace

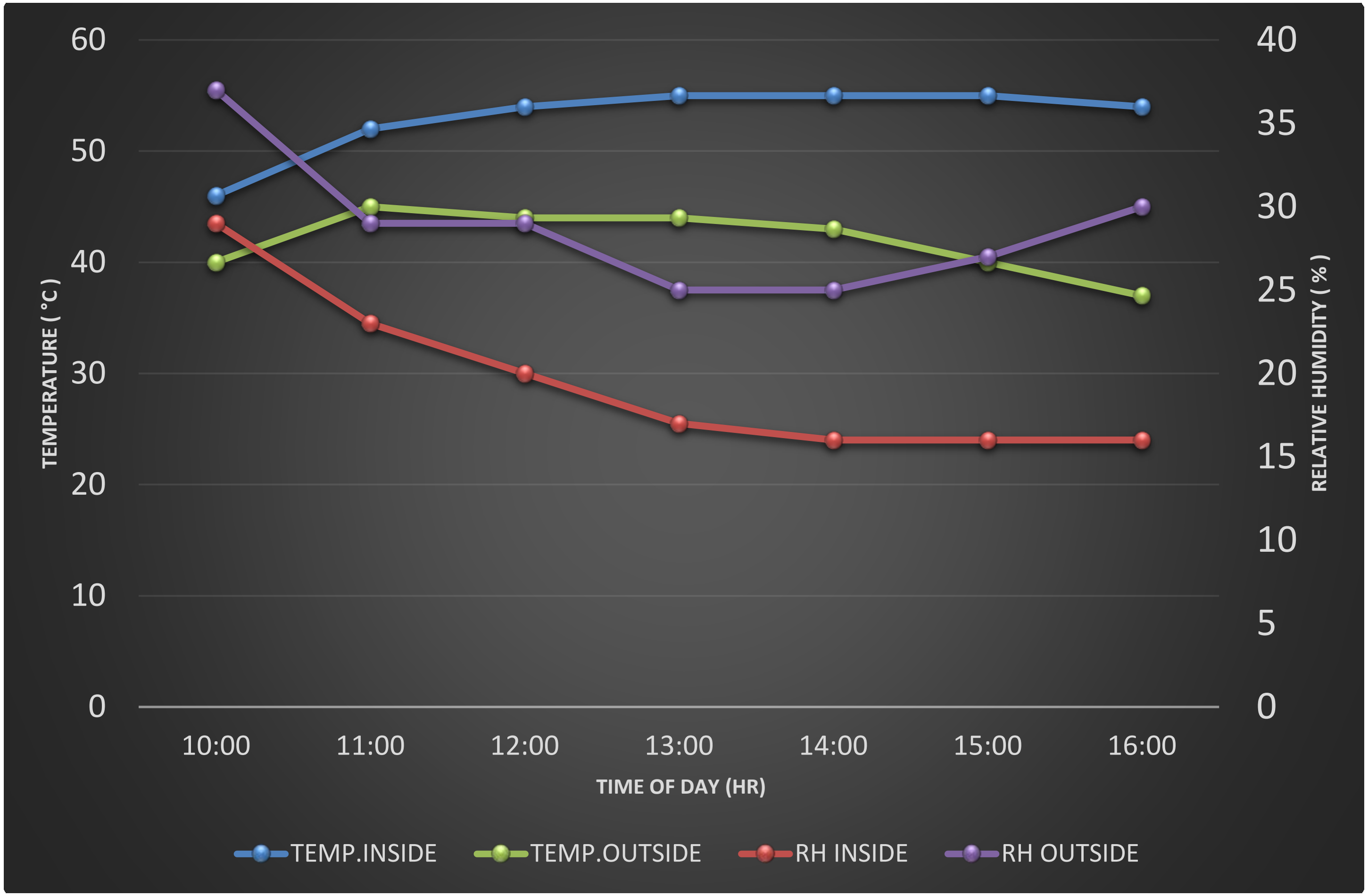
Solar biomass dryer



Biomass Furnace:

Heat exchanger coupled with an ID fan run by a 3hp motor powered by 2.2kW solar PV Modules with 1000 Amp deep cycle battery back up system

- Preliminary monitoring of temp and RH of dryer



Conditions were monitored over a clear weather condition

Assessment on economic impact of innovative system - renewable energy integration

- Develop economic model for Improved Case (I/C) scenarios with renewable energy (solar and biomass residue) input

- Compare results of I/C with Base Case B/C scenario (mechanical drying system) to assess impacts of renewable energy integration.

Technical and Financial Analysis of the solar biomass maize drier

Technical parameters and assumptions for the drier

Parameter	Value
Capacity of drier (tonnes)	5
Number of batches per day	2
Number of hours required per batch of drying	8
Operational hours per year	2,688
Size of a bag of maize (kg)	130
Number of bags dried per day	77
Number of bags dried per week	462
Quantity of maize processed per year (tonnes)	1,680
Number of bag of maize processed per year	12,923.08
Quantity of corn cobs required per hour (kg)	25.00
Quantity of corn cobs required per year (tonnes)	67.20
Average distance of farms to processing centre (km)	7
Cost of transportation of corn cobs per ton (USD)	11.43
Total quantity of maize produced per year in the district (tonnes)	30,266.80
Number of driers required to process the total available maize	18
Quantity of corn cobs available in the district (tonnes)	7,566.70
Quantity of corn cobs required by the total number of driers (tonnes)	1,210.67
Direct employment generated by the total number of driers (persons)	72
Lifespan of drier (years)	15
Price charged for drying a bag of maize (USD)	1.43

Cost benefit analysis

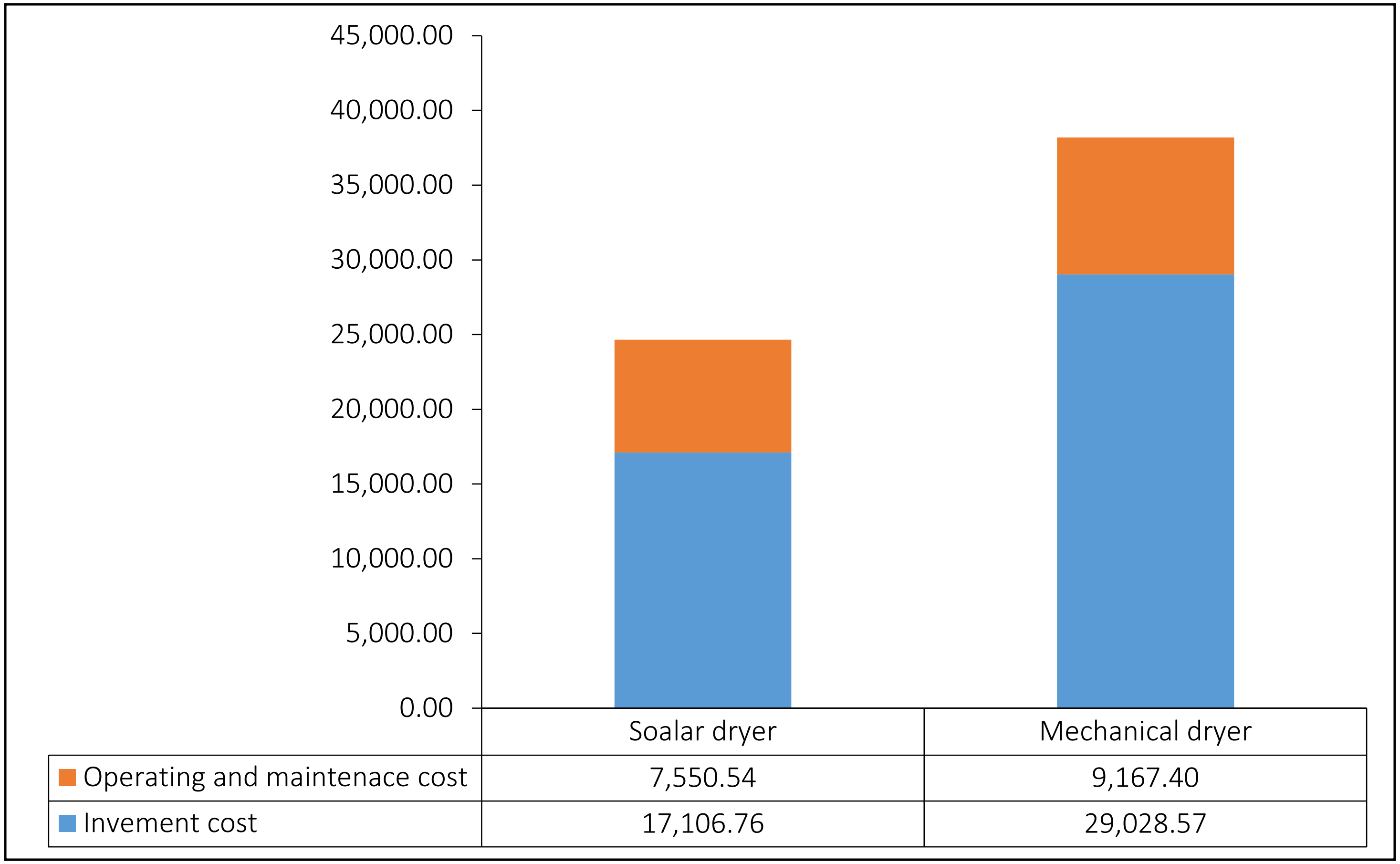


Figure 1: Investment and production cost for solar and mechanical dryer

NPV and IRR for the two systems (I/C and B/C)

Parameter	Solar drier	Mechanical drier
IRR 5years	57.12%	11.61%
IRR 15 years	63.74%	26.68%
IRR 20 years	-	27.25%
NPV	38,447.46	13,662.02

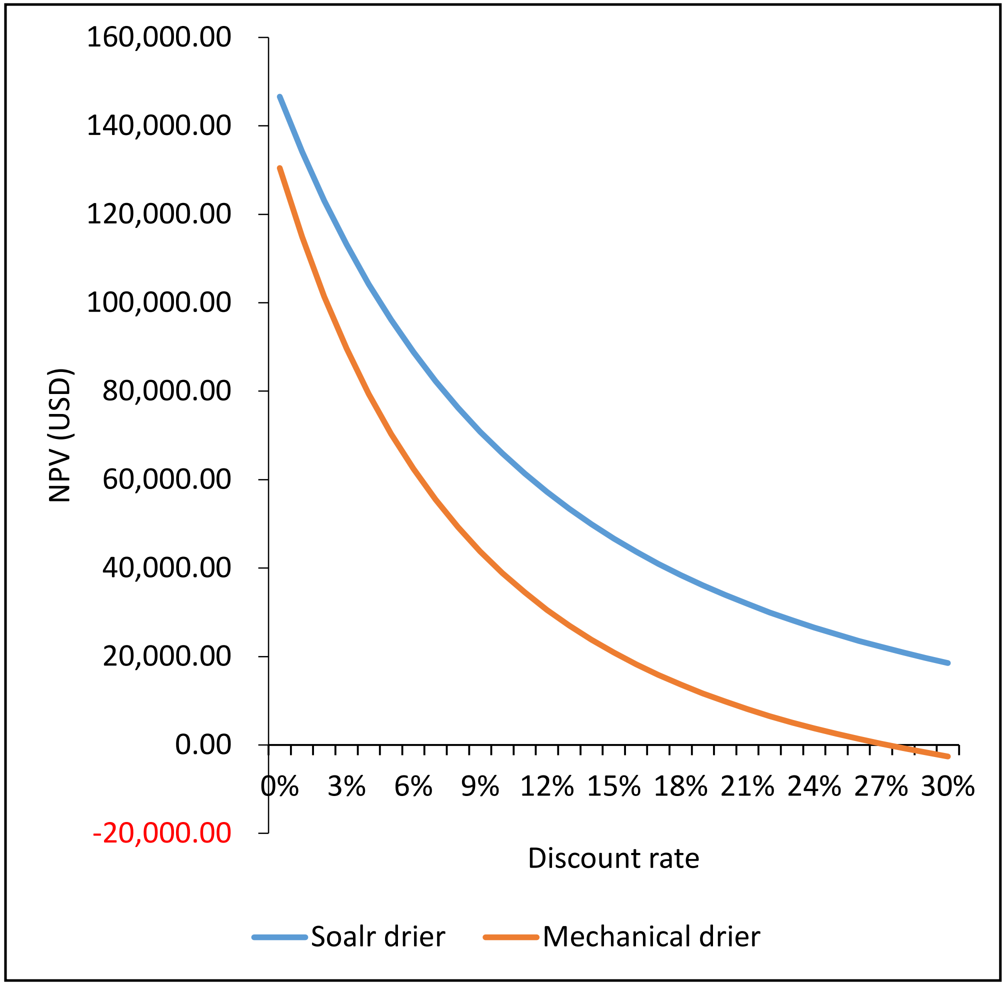


Figure 2:NPV curves for the two case scenarios

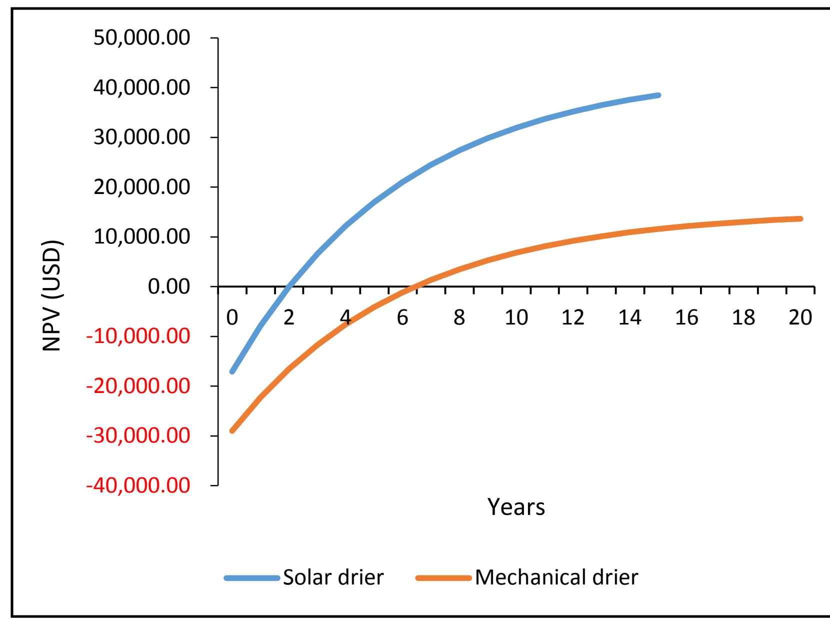


Figure 3:Variation of NPV over the lifetime of the two

Sensitivity analysis

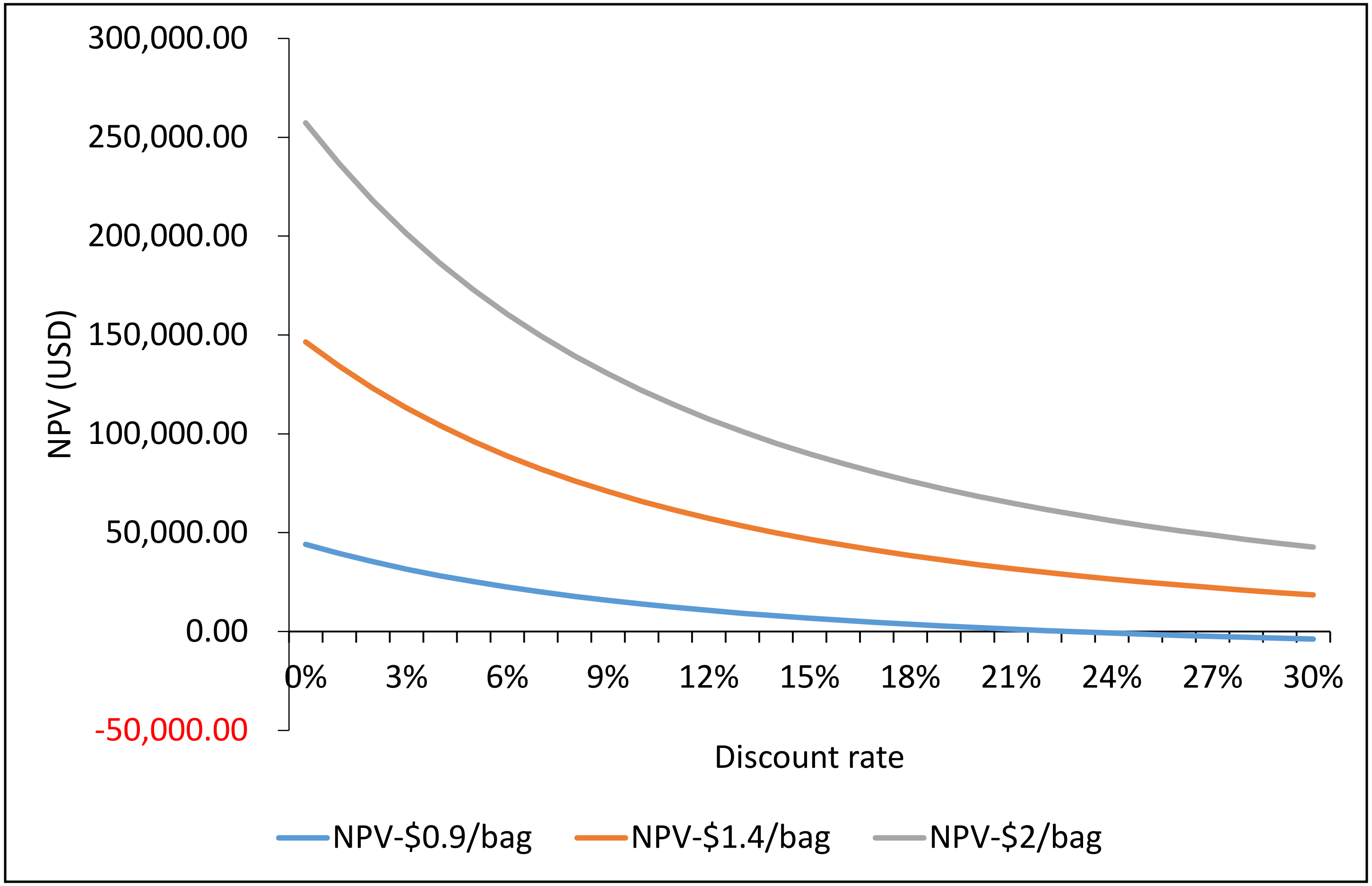


Figure 4: NPV curves for variation in cost for drying a bag of maize

Comparison on profitability of different drying methods to improved case scenario

Parameter	Solar drier	Mechanical drier	Sun drying
Number of bags for base scenario	10	10	10
Quantity of maize left after moisture loss (20% to 12%) (bags)	9.2	9.2	9.20
Percentage losses during drying	-	-	12%
Quantity of maize left after drying losses (bags)	9.2	9.2	8.10
Unit cost for drying a bag of maize(USD)	1.43	4.29	1.14
Total Cost of drying the maize (USD)	14.3	42.9	11.43
Price of a bag of maize (USD)	46	46	37.14
Net cash flow(USD)	409.43	380.83	289.28

Conclusion

- Reduction in production values of maize in major season can be addressed if an affordable drying system (I/C) is introduced

- 12,923 bags of maize can be processed annually which represents 5.56% of total maize produced in the municipality.

- 18 of the solar driers will be required to process the total quantity of maize estimated annually (30,266.80 tonnes) which can generate direct employment for 72 persons.

- The hybrid solar drier is financially viable with NPV and IRR of 38,447.46, 63.74%.

THANK YOU

DFID Department for International Development

EPSRC Engineering and Physical Sciences Research Council

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