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Economic Impacts of Mechanisation and In-House Renewable Energy Generation and Integration in African CPO Mills

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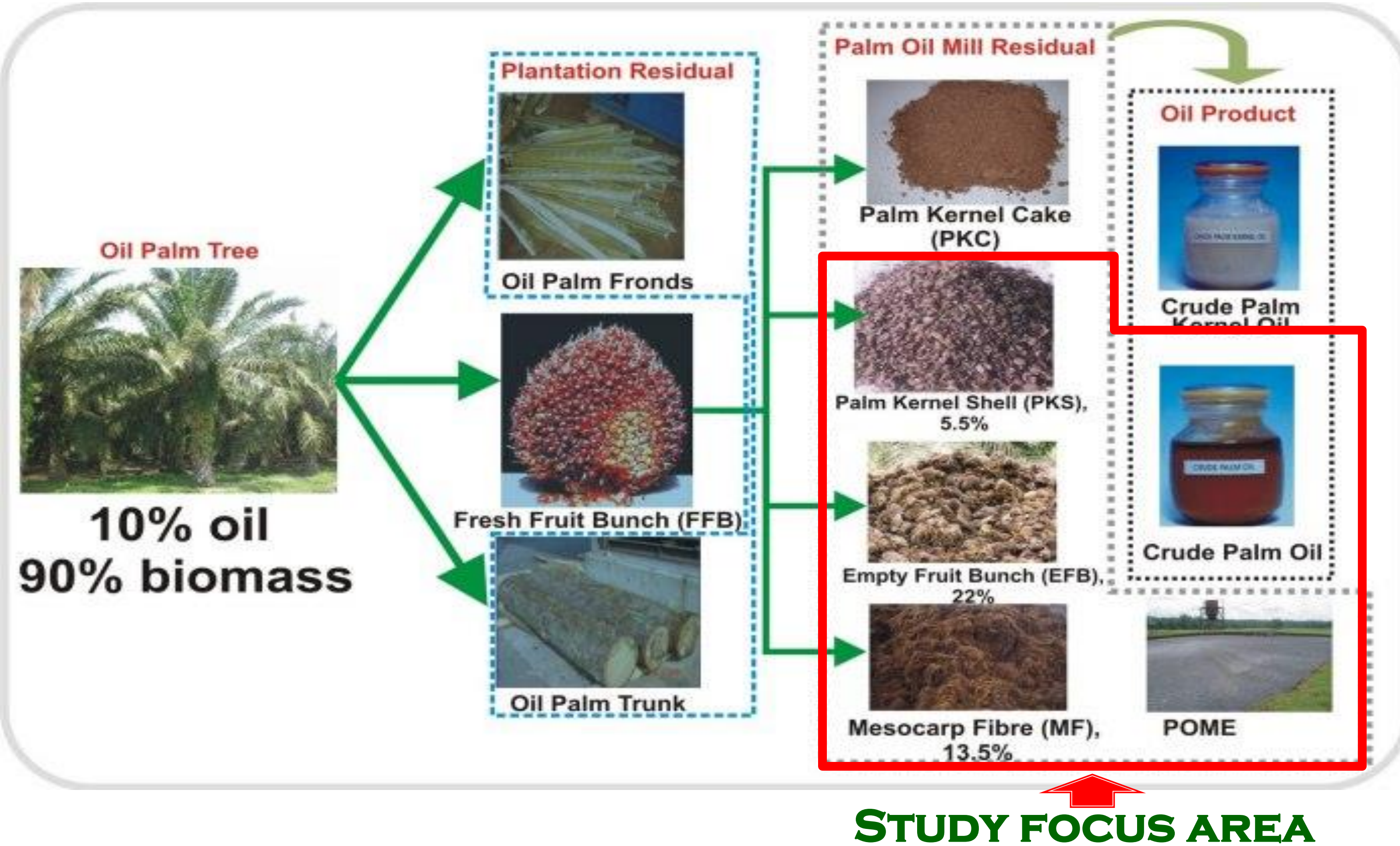
Overview

- Background
- Problem Statement
- Objectives
- Process Modelling Approach
- Results
- Conclusion

Background

Oil Palm value chain



Background

African rural CPO processing

- ✓ Dominating traditional Processing (>80 %)
- ✓ Inherent setbacks of traditional technologies
  - Lower production capacities
  - Labour Intensive
  - Poor product quality

Overall low productivity- Mechanisation addresses aforementioned challenges

Problem Statement

Reasons for less adoption of mechanised units?

- Perceived risk on profit margins
- Lack of diverse energy
- Social acceptance

Background | **Problem Statement** | Scope of Study | Objectives | Process Modelling Approach | Results | Conclusions

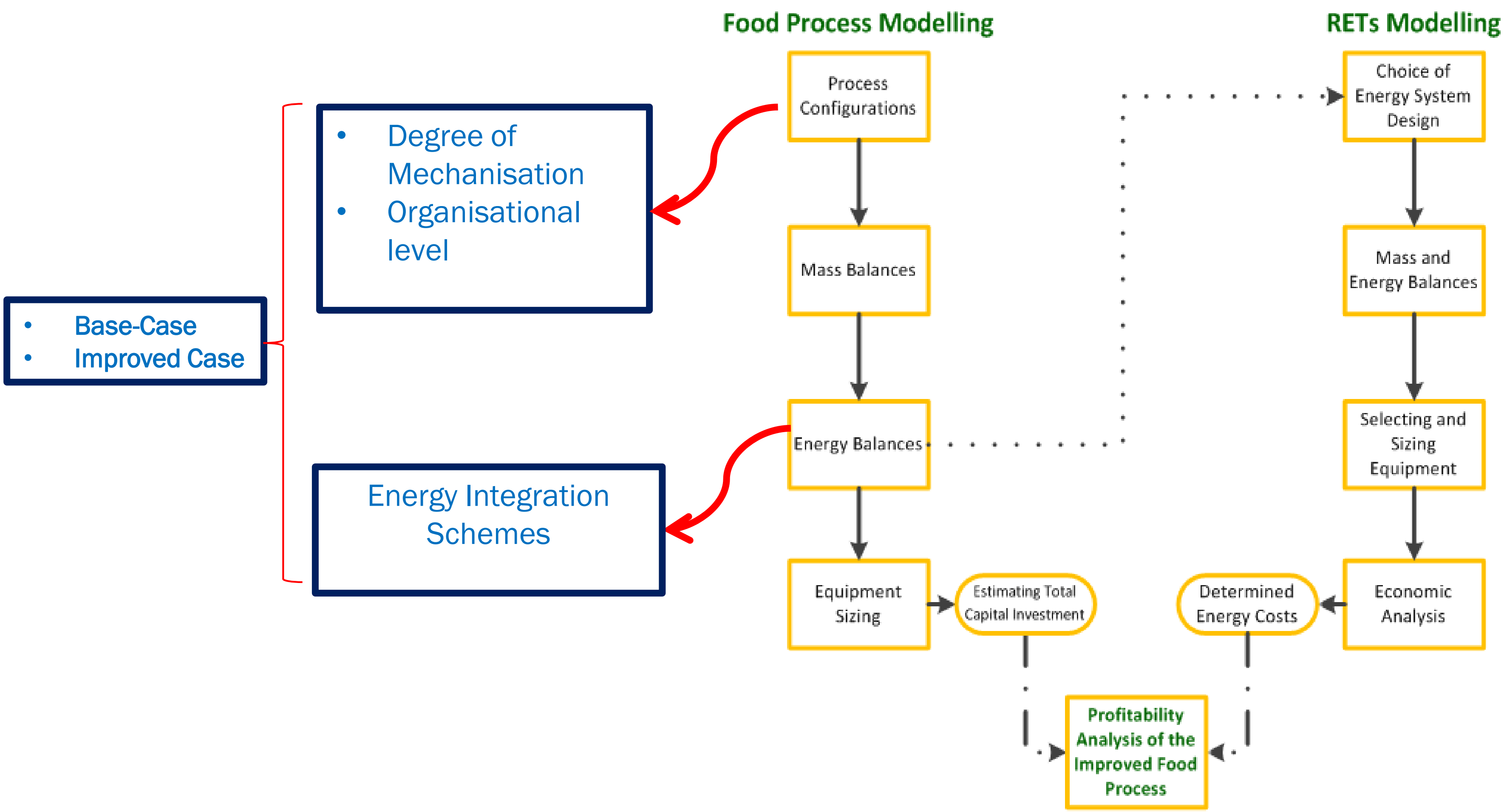
Objectives

Develop process models for various levels of mechanization in the CPO process

Determine the potential contribution of the process biomass residue to its energy demands.

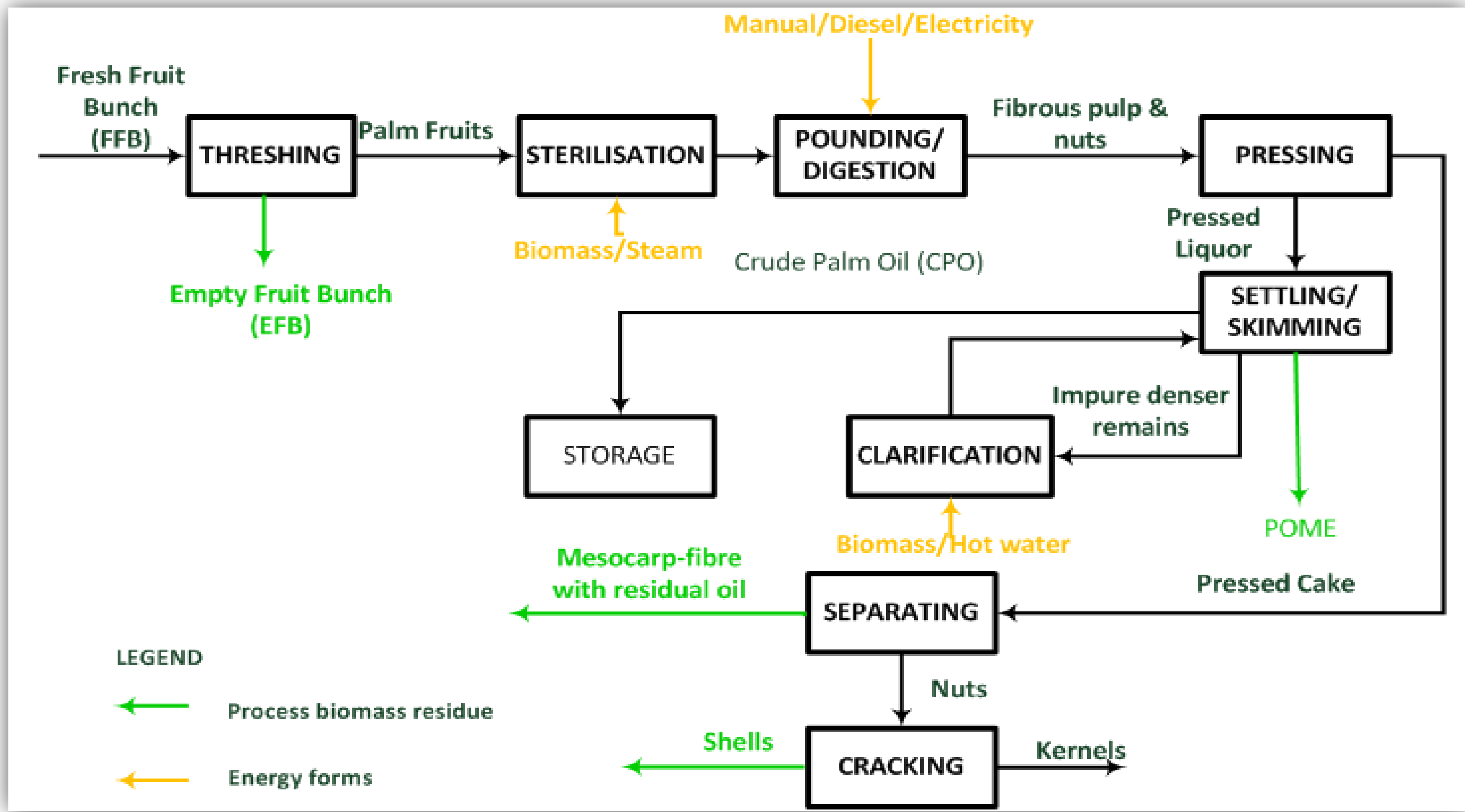
To establish the economic impact of mechanization and in-house energy integration in the CPO process

Modelling Approach



Background | Problem Statement | Scope of Study | Objectives | **Process Modelling Approach** | Results | Conclusions

Simplified CPO process flow diagram



Process configurations investigated

Traditional

- Household scale
- 110 liters CPO/day

Semi-Mechanised

- Small-scale
- 1193 liters of CPO/day

Mechanised

- Industrial scale
- 49287 liters CPO/day

In-house Energy Generation & Integration

Traditional and semi-mechanised

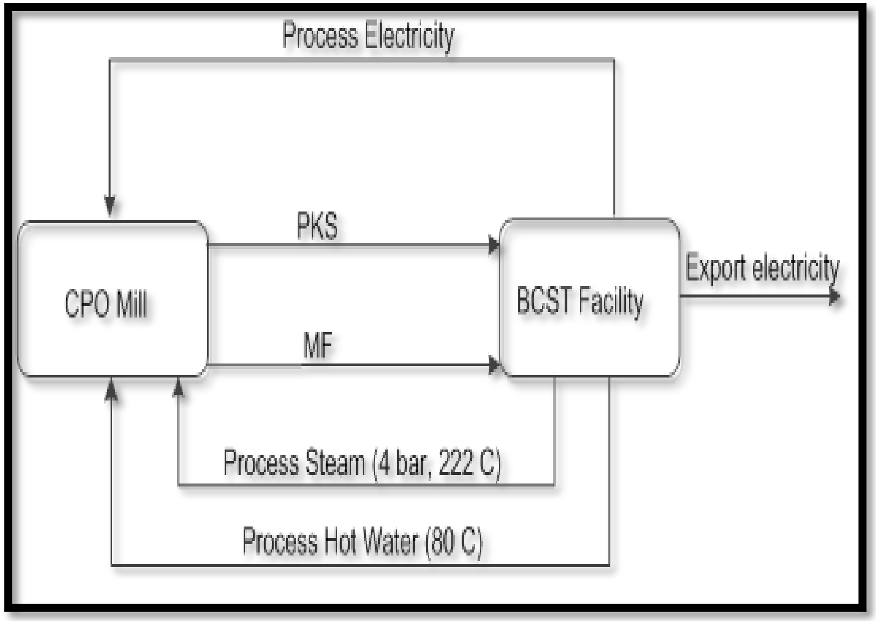
- Thermal energies by combusting solid residues in Improved cook stoves

Mechanised (**steam, hot water & electricity**)

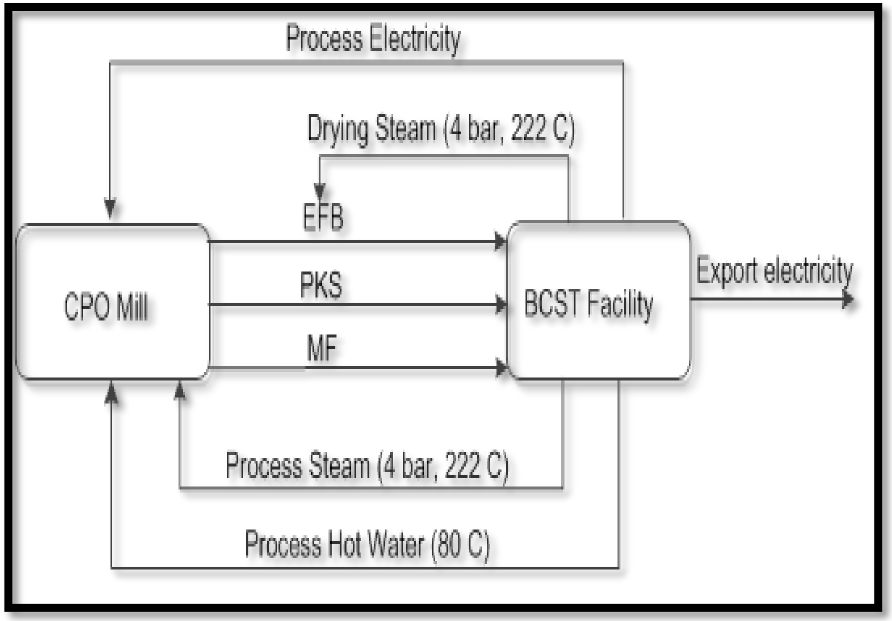
- Cogeneration of heat and power (CHP) from solid residues (MF, PKS, EFB)
- Cogeneration of heat and power from Biogas (POME)

Cogeneration (CHP) from **solid residues**

- EFB has high moisture (65%) & less combustible
- Two scenarios investigated:



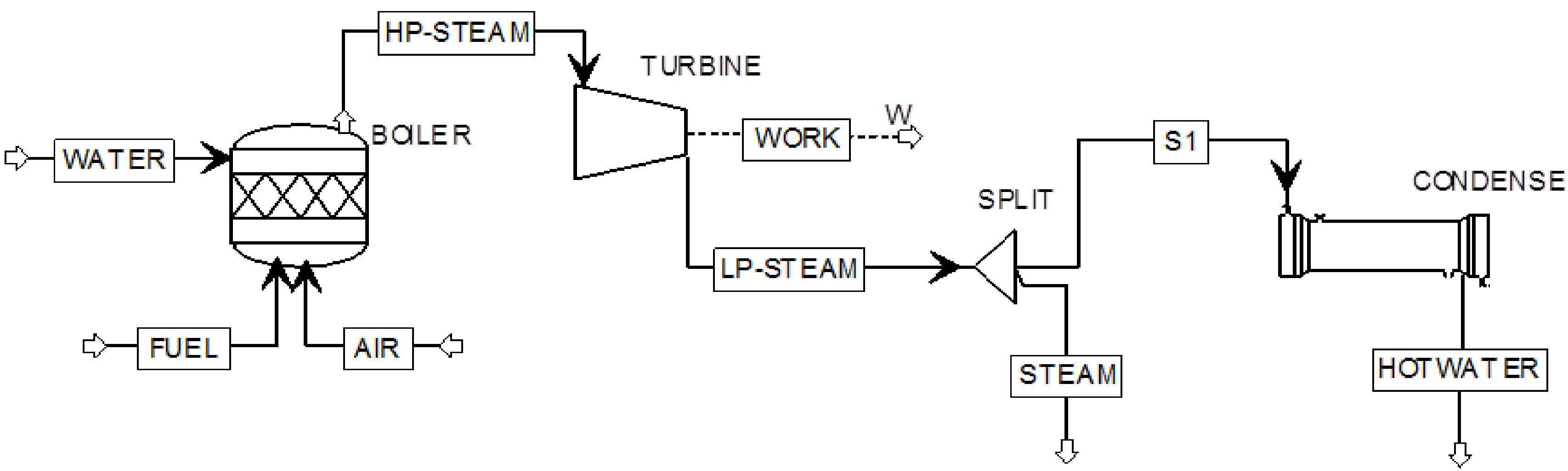
1: **No EFB** addition



2: Shredding & drying EFB + conventional fuel

Cogeneration (CHP) from **solid residues**

- Steam turbine power-to-heat ratio between 0.1 – 0.3 (US EPA, 2007)
- Process model developed in Aspen Plus® simulation software
- Economic assessment based on Ghana's year 2014 conditions (Interest rate -24%; Inflation rate -15%)



Cogeneration (CHP) from **solid residues**

Results

Technical Performance		
Annual rate of generation	Scenario 1	Scenario 2
MF (tons/yr)	13141.44	13141.44
PKS (tons/yr)	6836.47	6836.47
EFB (tons/yr)	-	45576.46
CPO Process steam (tons/yr)	40884.48(100)*	40884.48(100)*
CPO Process hot water (tons/yr)	31074.86(100)*	31074.86(100)*
EFB drying steam (tons/yr)	-	161840.62
CPO process electricity (MW/yr)	1654.85(100)*	1654.85(100)*
Export electricity (MW/yr)	**4705.64**	**17040.79**

* Values in parenthesis represents percentage of energy demand of the 13 ton FFB/hr CPO mill attained

Economic Performance				
Parameters	Electricity s.p. of $0.207/kWh		Electricity s.p. of $0.348/kWh	
	Scenario 1	Scenario 2	Scenario 1	Scenario 2
NPV (million $)	-27.96	-55. 91	-22.03	-38.85
IRR (%)	0.10	1.42	9.94	12.93
Payback period (yrs)	24.8	23.2	15.5	13

Cogeneration (CHP) from **solid residues**

Conclusions

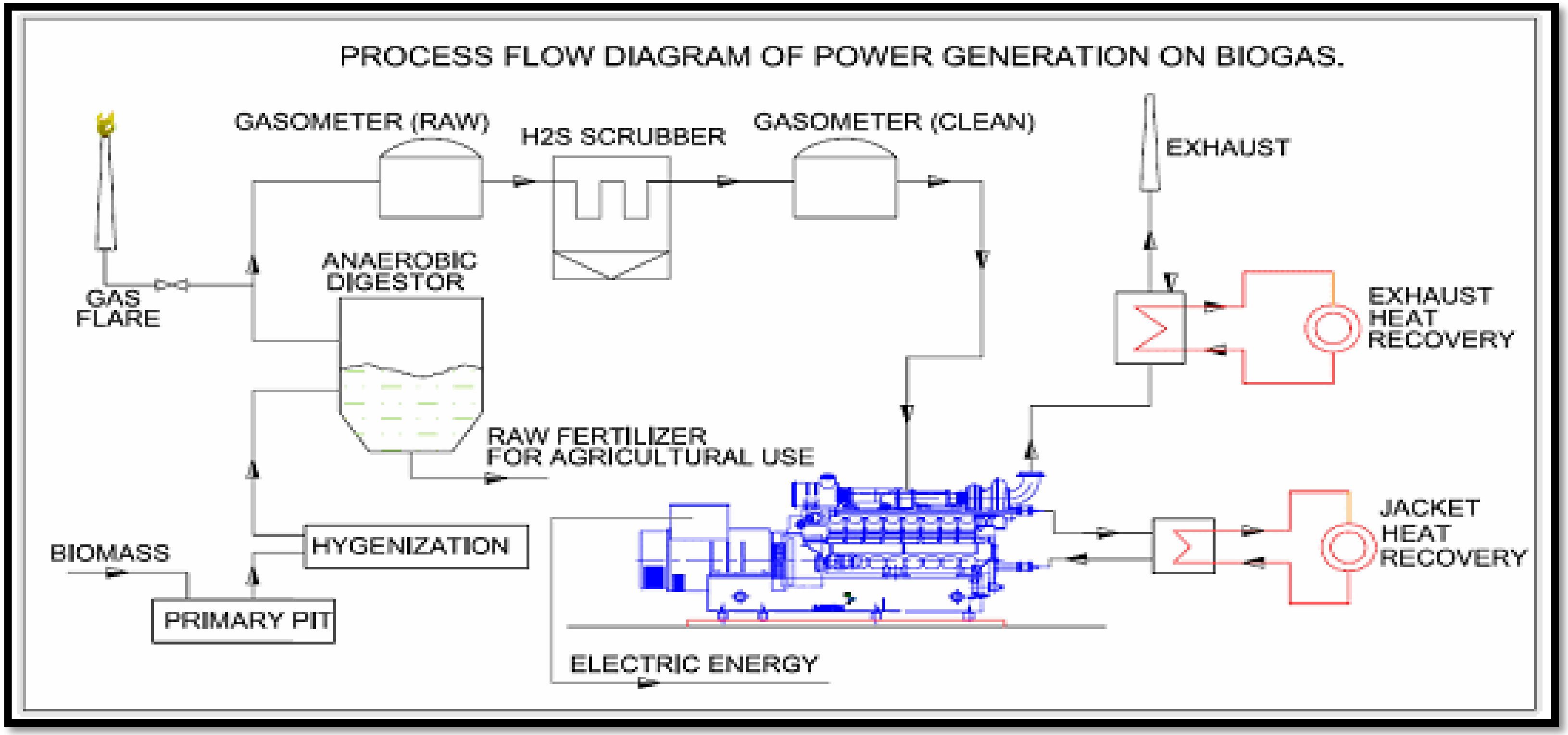
- Both Scenarios investigated **CAN MEET** in-house energy demand with excess electricity for export.
- Scenario 1 and 2 did **NOT** achieve expected IRR of 40%. Scenario 2 (EFB addition) improved the economics from IRR of 9.94% to 12.93%
- Realistic electric price at **$1.132/kWh** and **$0.842/kWh** for Scenario 1 and Scenario 2 respectively (for IRR of 40%).
- Scenarios 1 and 2 attained NPVs of $2.145 million and $1.774 million at grant contributions of 80 and 65% respectively at prevailing power price of $0.348/kWh. Thus both are viable under grant funding.

Cogeneration (CHP) from **Biogas (POME)**

- Palm oil mill Effluent (POME) biogas yield of 2.65 - 4.96 $m^3 m^{-3}$ day^{-1} (Yeoh, 2004).
- Scenarios investigated: Steam-turbine and Gas-engine routes
- CHP process modelled in Aspen Plus® simulation software
- Economic assessment based on Ghana's year 2014 economic conditions (Interest rate -24%; Inflation rate -15%)

Cogeneration (CHP) from **Biogas (POME)**

- Steam turbine process- **similar to solid residue CHP**
- Gas-engine process



Cogeneration (CHP) from **Biogas (POME)**

Results

Technical Performance		
Annual rate of generation	Gas-engine route	Steam turbine route
Biogas (tons/yr)	2073.326	2073.326
CPO Process steam (tons/yr)	2308.198 (5.65)*	11742.602 (28.72)*
CPO Process hot water (tons/yr)	29880 (96.16)*	-
CPO process electricity (MW/yr)	1654.85 (100)*	368.865 (22.29)*
Export electricity (MW/yr)	1117	-

*** Values in parenthesis represents percentage of actual energy demand by the 13 ton FFB/hr CPO mill attained**

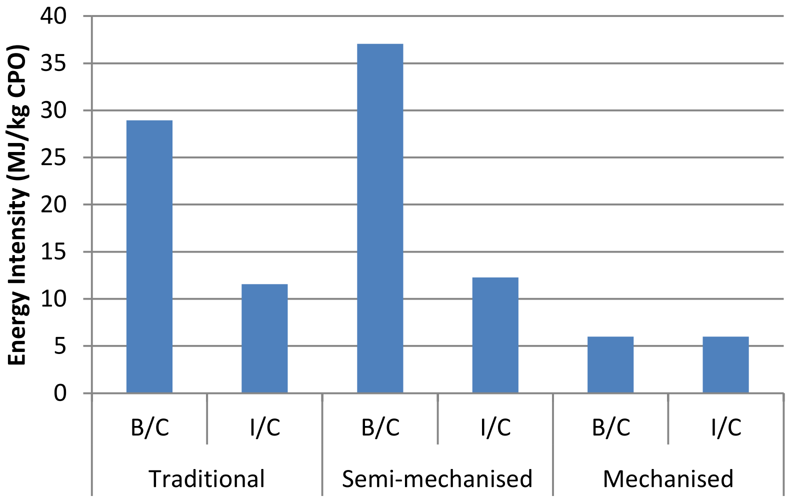
Economic Performance				
Parameters	Electricity s.p. of $0.207/kWh		Electricity s.p. of $0.348/kWh	
	Gas-engine	Steam turbine	Gas-engine	Steam turbine
NPV (million $)	-6.38	-14.46	-4.71	-14.22
IRR (%)	7.80	-0.77	14.89	0.18
Payback period (yrs)	11.3	14.3	9	13.7

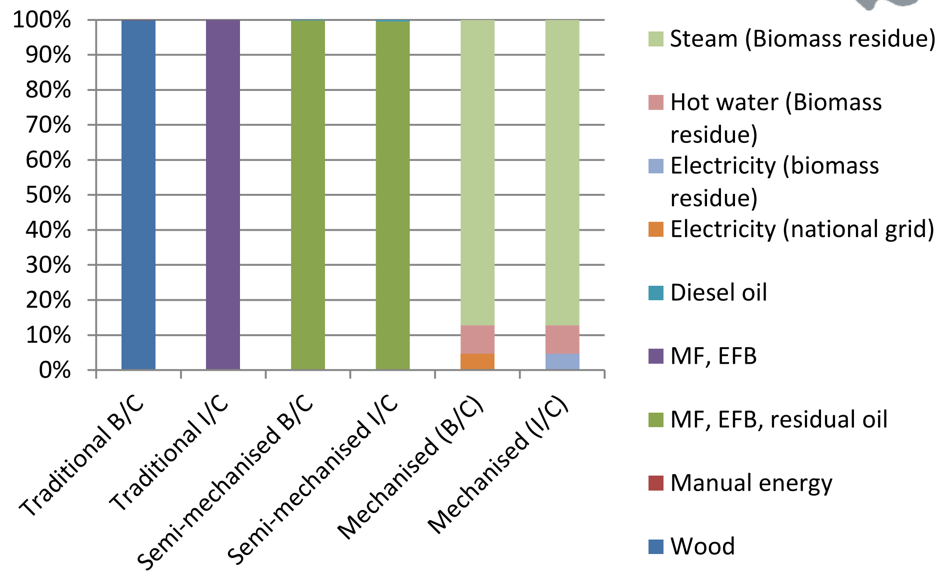
Cogeneration (CHP) from **Biogas (POME)**

Conclusions

- Gas-engine and steam-turbine **NOT** meet all in-house energy demand. Gas-engine route attained all process electricity demand with excess for export.
- Both routes investigated did **NOT** attain expected IRR of 40%. **Gas-engine** route **more promising** with IRR of **14.9%** at $0.348/kWh.
- Realistic electricity price at **$0.753/kWh** and **$9.403/kWh** for gas-engine route and steam-turbine route respectively (for IRR of 40%)
- At power price of $0.348/kWh, Gas engine attained NPV of $158000 at 40% grant; steam turbine NPV of $1.834 million at 90% grant. At $0.207/kWh, gas-engine NPV of $234000 at 60% grant; steam turbine NPV of $576000 at 90% grant. Thus both viable under grant funding.

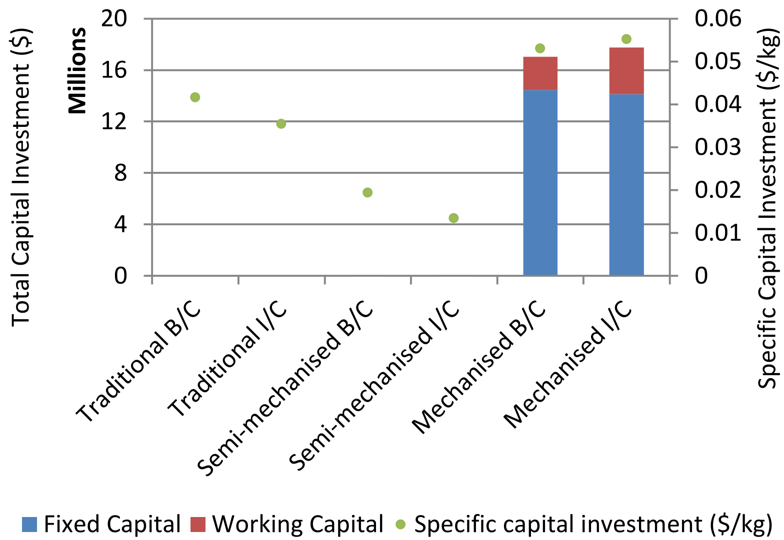
Results of Energy Integration in CPO Processes

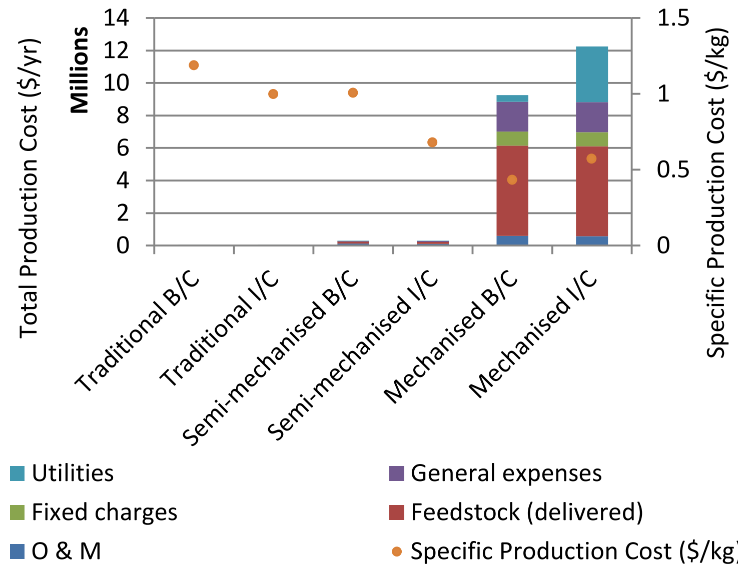




- Mechanised I/C – **adopted CHP solid residue (+EFB)** (100% in-house energy attained & competitive power price of $0.842/kWh)
- Substituting external energy firewood (traditional), and national grid power (mechanized) with available CPO process biomass residues is feasible.
- The highest and least energy intensive processes: **semi-mechanized B/C** (37.058 MJ/kg CPO) and **mechanized B/C or I/C** (6.007 MJ/kg CPO) respectively.

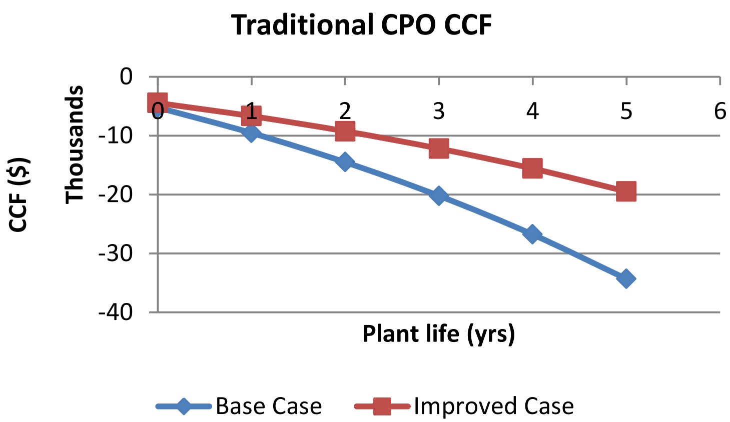
Economic Results of CPO Process



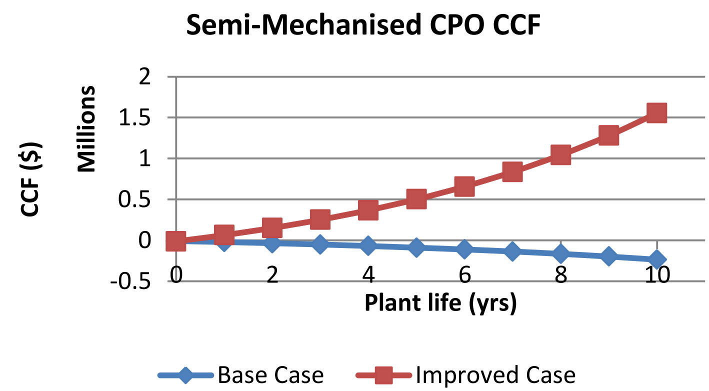


- Variation in TCI ranging $4464 - $17.746 million due to difference in capacities
- SCI ranging $0.013/kg - $0.055/kg with semi-mechanised level having least range of $0.013 - 0.019/kg while mechanised level attained highest range of $0.053 - 0.055/kg
- At B/C scenarios, traditional level's SPC was higher than the semi- and mechanised level's by 15.25% and 63.66% and by 31.90% and 42.73% at I/C scenarios respectively. Thus, suggesting a high benefit of economies of scale on the production cost.

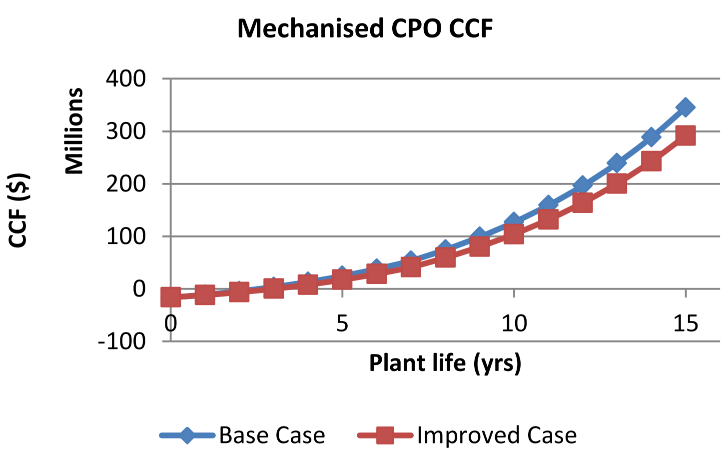
Economic Results of CPO Process



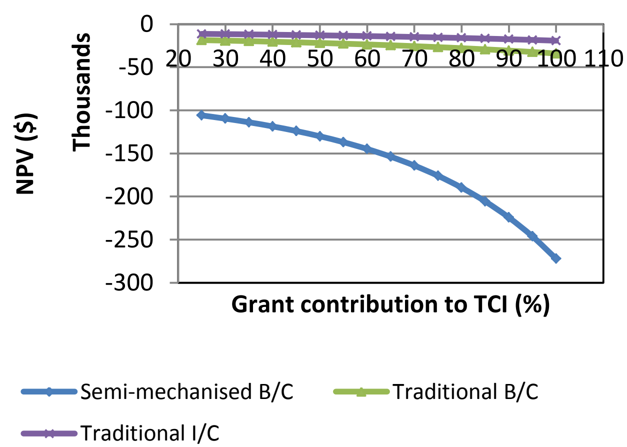
NPV of - $ 16,212 & -$10,110



NPV of -$109,334 & $301,643



NPV of $18,500,245 & $11,501,445



NB: At minimum selling price of $710/ton CPO

Key:
CCF –Cumulative Cash Flow
NPV- Net Present Value

Conclusions

- For (B/C), **only the mechanized** process is economically viable with an NPV of $18.5 million and IRR of 47.23%.
- For I/C: **semi-mechanized** and **mechanized** processes are the economically viable options with IRR of **143%** and **40.57%** respectively.
- Poor performances of traditional- B/C & -I/C and the semi-mechanized B/C mainly due to their unduly high SCI ranging $0.019 – 0.053/kg and SPC between $0.431 – 1.187/kg as they still remained unviable under 100% grant funding
- Thus mechanization is economically beneficial in CPO processing
- In-house energy from process residue is viable and most promising at **semi-mechanized** and **mechanized** levels.

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