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Utilising Renewable Energy to Improve African Rural Food Processing

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SU Activities WP 2

- T-2.2 Assess the extent of rural food processing, the technologies utilised, the energy mix and level of inputs currently required.
- T2.3 Identify the potential for various forms of renewable energy and assess existing deployments in rural regions.
- T-2.5 Identify successes, limitations and failures of business models for food processing and renewable energy enterprises and demonstrations of existing activity.
- T2.6 Identify any existing best practice and learning opportunities/barriers for both food processing and renewable energy applications.

SU activities WP3

T3.1 Evaluate innovative food processing technologies and practices which increase the food quality decrease the yield gap and maximise the use of renewable energy sources.

T3.2 Develop techno-economic models for integration of renewable energy and food processing.

T3.3 Assess potential impact of changes on capital investment, job creation, income generation, decreased post-harvest losses and energy costs.

WP2-Task 2.2

Assess the extent of rural food processing, the technologies utilised, the energy mix and level of inputs currently required

WP2: T2.2- Food processes Selected

- Maize flour (MF)

- Cassava flour (CF)

- Crude palm oil processing (CPO)

Overall Selection Criteria

- Potential production capacity
- Extent of food losses
- Contribution to local diets
- Economic value

WP2-Task 2.2: Motivation for food processes selected

- Maize flour:
  - Complementing the work by KNUST.
  - Targeting RE application in whole value chain
  - Staple food in many African countries

- Expected Output: Joint publication with KNUST on renewable energy application in the maize value chain

WP2-Task 2.2: Motivation for food processes selection

- Cassava flour:
  - Highly perishable
  - Challenges similar to handling highly perishable fruits and vegetables.
  - Complimenting work by JKUAT
  - Staple food for many African countries

- Expected Output: Modelling framework to be shared with JKUAT

WP2-Task 2.2: Motivation for food processes selected

- Palm oil Processing
  - Model food process.
  - Information easily accessible
  - Therefore, process as a benchmark for other food processes

- Expected Output: Modelling framework

WP2-Task 2.2: Food processing technologies

	Traditional	Semi-Mechanised	Mechanised
Maize flour	 • Household scale • 195 kg flour/week	 • Small-scale • 870 kg flour/day	 • Industrial scale • 1800 kg flour/day
Cassava flour	 • Household scale • 8.8 kg flour/day	 • Small-scale • 1.5 tons flour/day	 • Industrial scale • 6 tons flour/day
Crude palm oil	 • Household scale • 110 liters CPO/day	 • Small-scale • 1193 liters of CPO/day	 • Industrial scale • 49287 liters CPO/day

WP2-Task 2.2: Energy mix in food processing

- Solar: Often as thermal/sun-drying energy
- Bioenergy (Biomass):
  - Sources of thermal heating energy
  - Conversion by combustion in cook-stoves/tripod stoves
- Electricity:
  - From national grid
  - Mostly used in mechanised/industrial facility levels
- Fossil fuel:
  - In the form of diesel, petrol or LPG
  - Often used in small-scale facilities e.g engine driven hammer mills

WP 2-Task 2.3

T2.3 Identify the potential for various forms of renewable energy and assess existing deployments in rural regions.

WP 2-Task 2.3: Potential renewable energy and deployments

Solar:

- Technical potential in Africa:
  - Concentrated Solar Power (CSP) = 539 GW
  - Photovoltaic (PV) = 750 GW .

Hydro:

- Africa’s hydro power potential = 199.8 GW
- Africa’s exploited potential = 5%

Biomass:

- About 57.6% of total SSA energy needs (excluding South Africa)

WP 2- Tasks 5 & 6

T-2.5 Identify successes, limitations and failures of business models for food processing and renewable energy enterprises and demonstrations of existing activity.

T2.6 Identify any existing best practice and learning opportunities/barriers for both food processing and renewable energy application

WP 2- Tasks 5&6: Business models limitations and success factors

Limitation

- ***Capacity and Capital constraints***:
  - Limited to household scale
  - Scaling up hampered by high investment cost

- **Wood fuel** :
  - Household cooking e.g. use of wood-fuelled tripod stoves thermal efficiencies <15%
  - Over exploitation leading to deforestation

WP 2- Tasks 5&6: Business models success factors

Capacity and Capital constraints:

- Establishment of small-scale CPO processing
  - Done in small-cooperative (4 -12 members).
  - Each member brings own workers
  - Benefits are extended to broader community.
  - Scaling up of operations
  - Shared investment cost

WP 2- Tasks 5&6: Business models success factors

Inefficiencies of wood fuel:

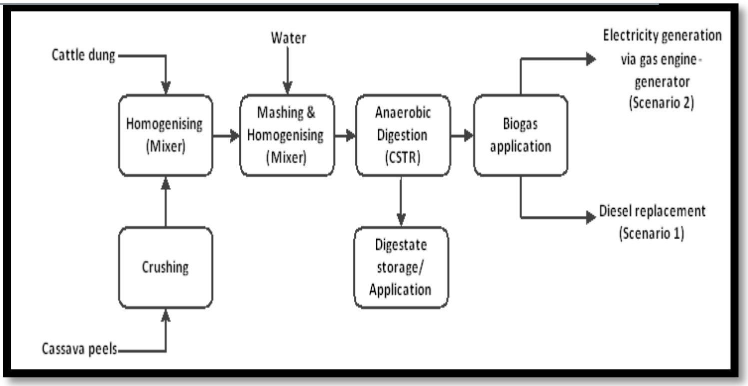
- Improved cook-stoves (efficiencies > 30%)
- Compliment or substitute agro-residues (field or process residues).
- Use of biomass residues generated within the food process/ value chain

WP 2 Task 2.6: Learning opportunities/barriers for both food processing and renewable energy application

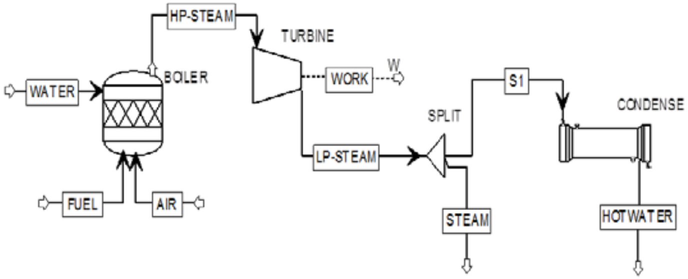
Strategic use of biomass residues for process energy generation

Maize flour : Semi-mechanised & mechanised - **Cobs as drying fuel**

Cassava flour : Semi-mechanised & mechanised- **Anaerobic digestion (AD) of peels/cattle dung to electricity/dryer fuel**



Crude palm oil: mechanised- **Cogeneration of steam and electricity from process solid residues (MF, PKS, EFB)**



WP 3.1

T3.1 Evaluate innovative food processing technologies and practices which increase the food quality decrease the yield gap and maximise the use of renewable energy sources.

WP 3 Task 3.1: Technologies/practices which increase food quality/yield

African rural food processing:

- ✓ Dominating traditional processing (**>80 %**)
- ✓ Setbacks of traditional technologies
  - Inefficient/lower production capacities
  - Labour Intensive
  - Poor product quality

Overall low productivity- **Mechanisation of the process addresses aforementioned challenges**

Reasons for less adoption of mechanised units?

- **Perceived risk on profit margin**
- **Lack of diverse energy (modern energy e.g. electricity/diesel to power mechanised units)**

WP 3 Task 3.1: Technologies/practices which maximise use of renewable energy

- Biogas digesters: Convert biomass and liquid waste into biogas
- Biomass/Biogas-electricity technologies e.g. gas-engine gensets, biomass-fired boiler/steam turbine etc.
- Improved Cook-stoves: Efficiently combust solid biomass/biogas for heat applications
- Biomass fired-dryers: Suitable for large scale drying, drying in rainy season (no solar thermal energy available)

WP3

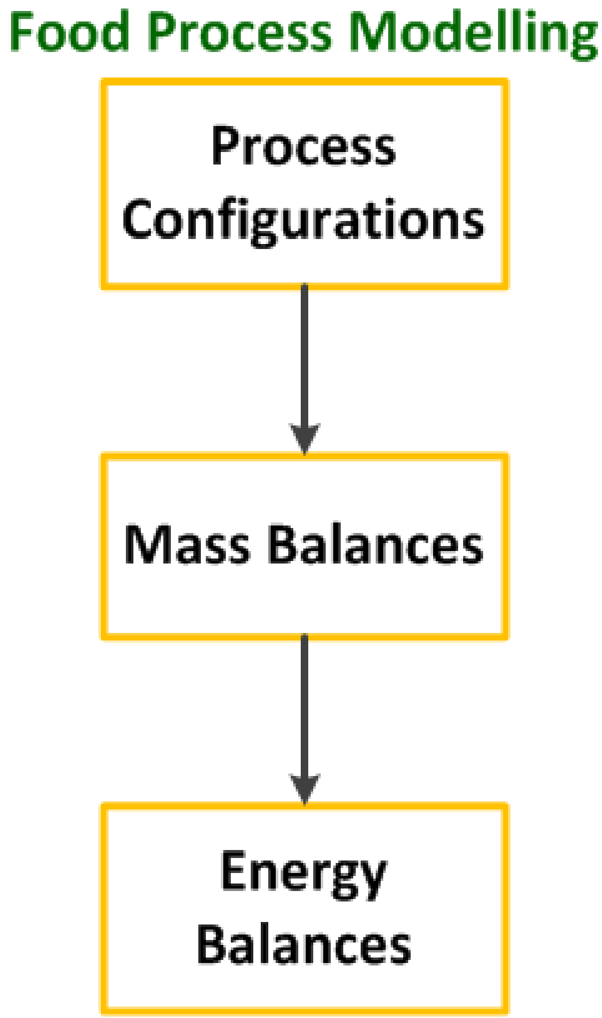
T3.2 Develop techno-economic models for integration of renewable energy and food processing.

WP 3 Task 3.2: Techno-economic models: Steps

STEP 1.

- Establish concepts for assessment of impacts of mechanisation on economics:

- Develop **PROCESS MODELS** for traditional, semi-mechanised and mechanised levels



WP 3 Task 3.2: Techno-economic models: Steps

STEP 2. Establish concepts for assessment of impacts of renewable energy integration

- Consider feasible renewable energy sources (focused on bioenergy from biomass residues).
- Develop models for Base-case (B/C) scenarios with conventional energy sources presently employed e.g. electricity from national grid

WP 3 Task 3.2: Techno-economic models: Steps

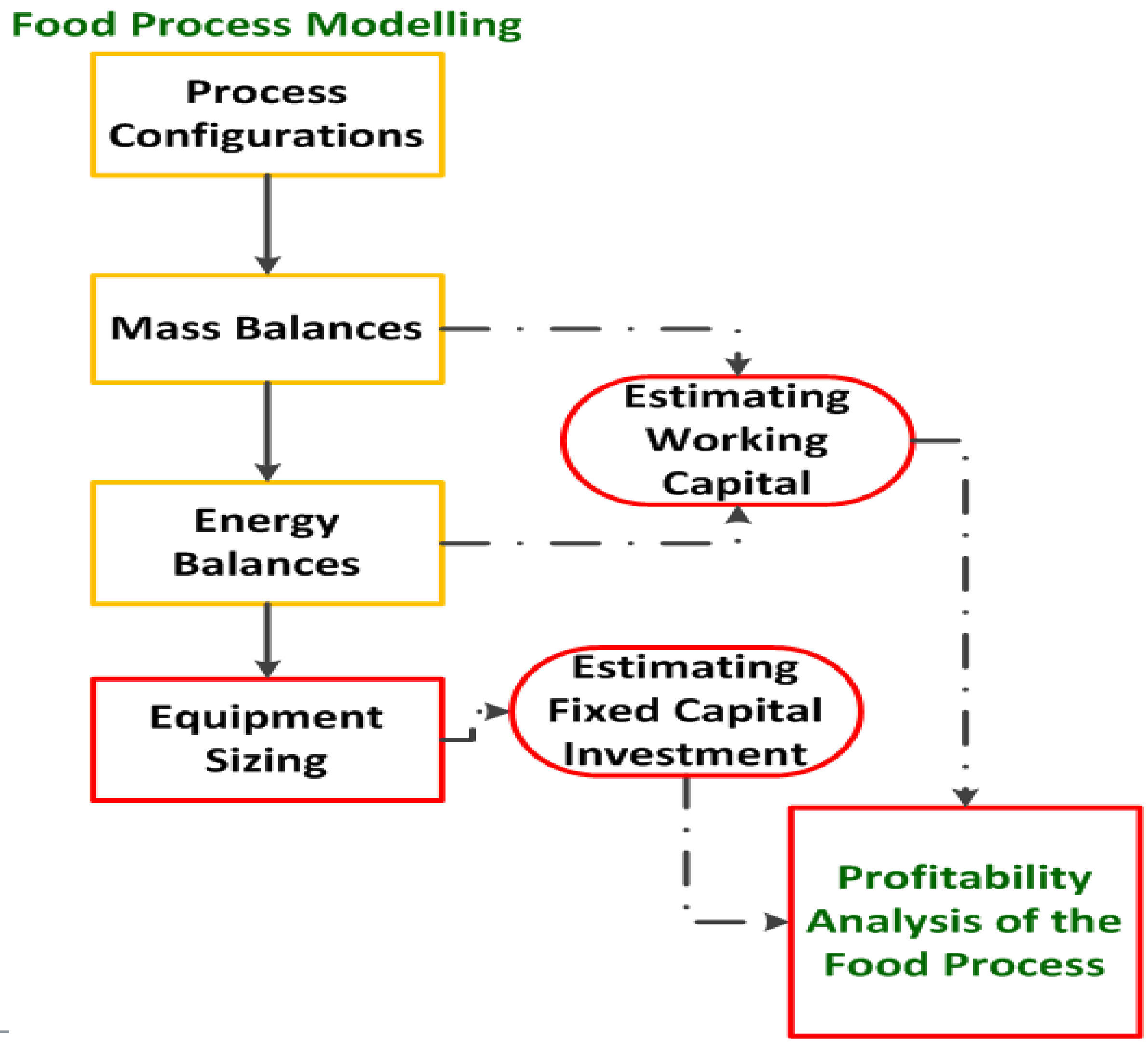
STEP 2. Establish concepts for assessment of impacts of renewable energy integration contd…

- Develop models for corresponding Improved Case (I/C) scenarios with renewable energy from process biomass residue e.g. electricity from biomass residue

- Comparing results of B/C with corresponding I/C scenarios help assess impacts of renewable energy integration.

WP 3 Task 3.2: Techno-economic models: Steps

STEP 3. Develop economic models for each food process model.



WP 3 Task 3.2: Techno-economic models: Steps

Renewable energy Modelling

STEP 4.

- Establish basis for calculating cost of generating energy, e.g. electricity/steam from solid biomass residues.
- Develop process/economic models to obtain "expected energy prices".

Choice of Energy System Design

Mass and Energy Balances

Selecting and Sizing Equipment

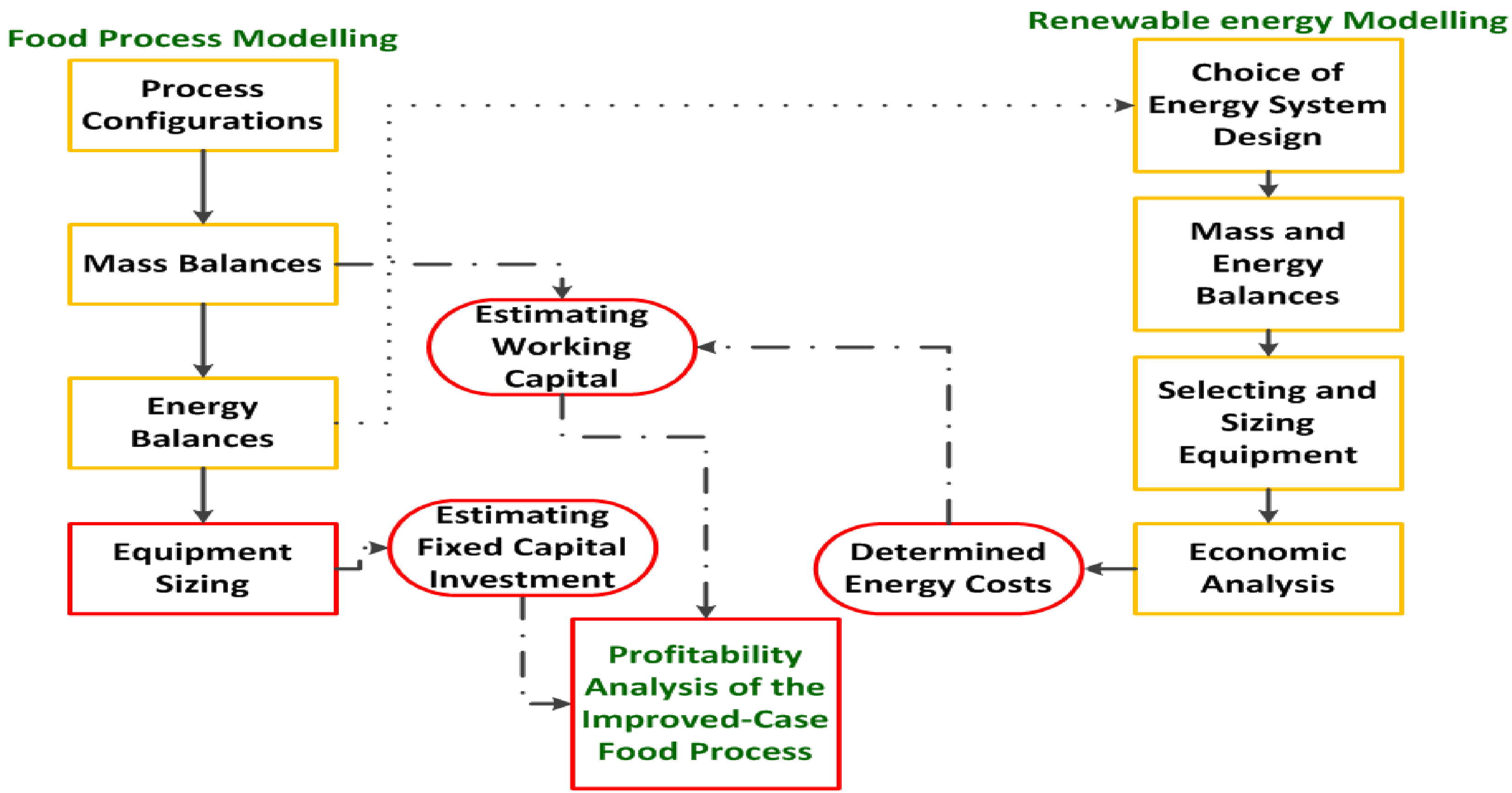
Economic Analysis

Determined Energy Costs

WP 3 Task 3.2: Techno-economic models

STEP 4. Continuation:

- Use obtained "expected energy prices" in economic assessment for the Improved Case (I/C) food process.



WP 3 Task 3.2: Techno-economic models; Case studies

CASE STUDIES CONSIDERED:

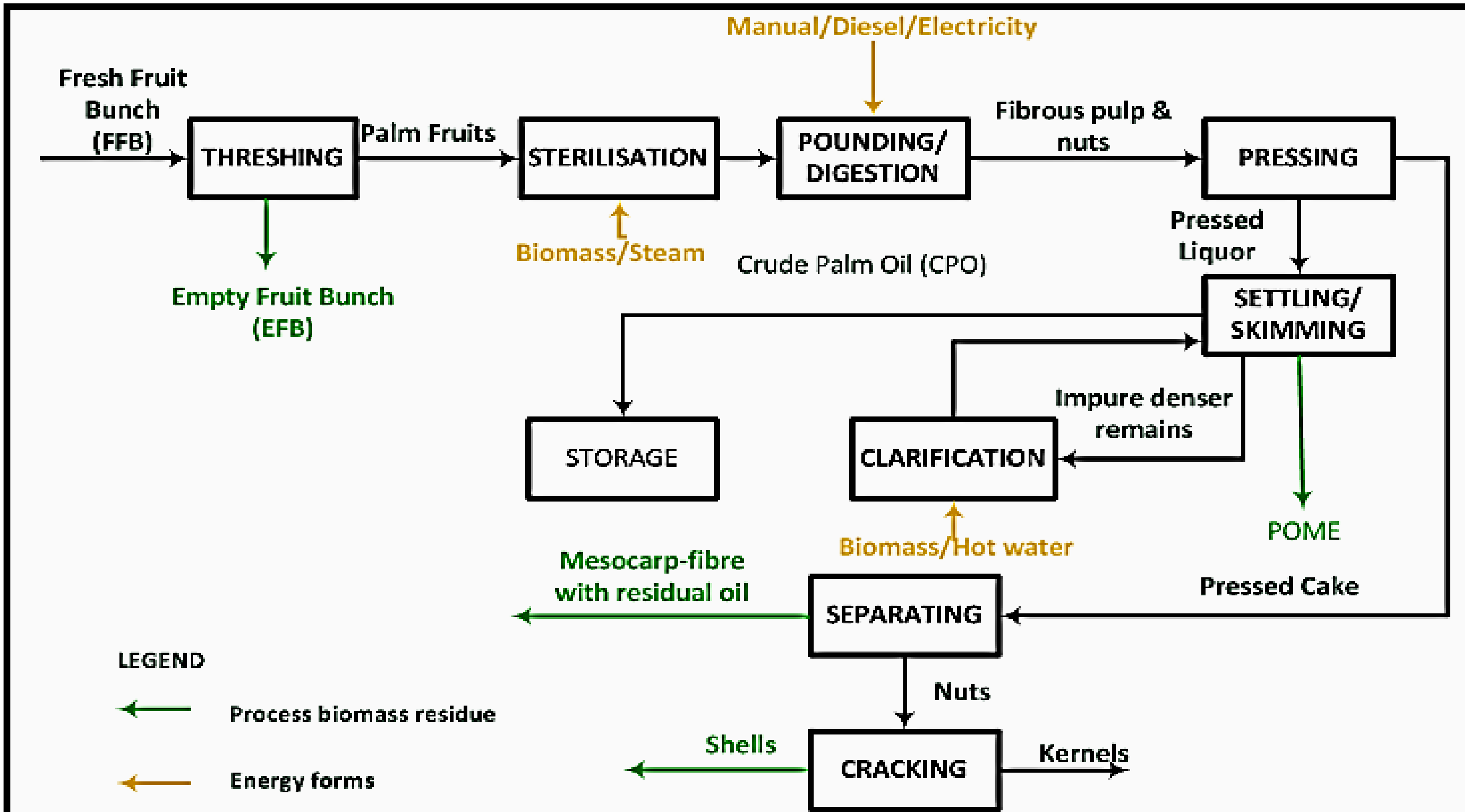
- Techno-economic models developed for the selected food processes; Crude palm oil (CPO), Maize flour (MF), and Cassava flour (CF)

- Energy integration from residues considered:
  - Mechanised CPO - **Cogeneration of heat and power (electricity) from process solid residues (MF, PKS, EFB)**
  - Semi-mechanised & mechanised MF processes - **Cobs as drying fuel**
  - Semi-mechanised & mechanised processes CF processes: **Biogas from cassava peels/cattle dung to electricity/dryer fuel**

- All economics performed under Ghana's 2014 economic context

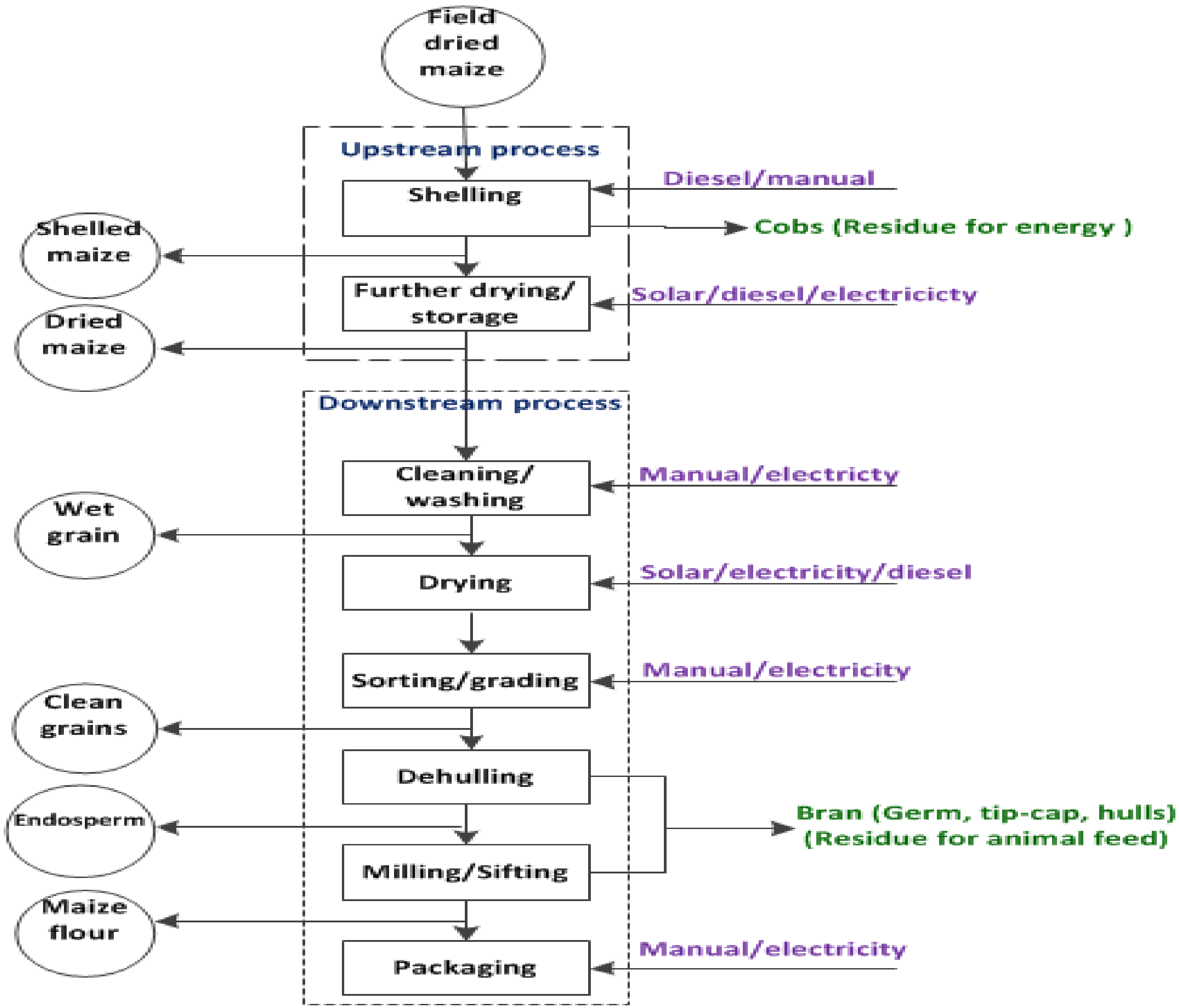
WP 3 Task 3.2: Techno-economic models; Case studies

Simplified Crude palm oil (CPO) process diagram



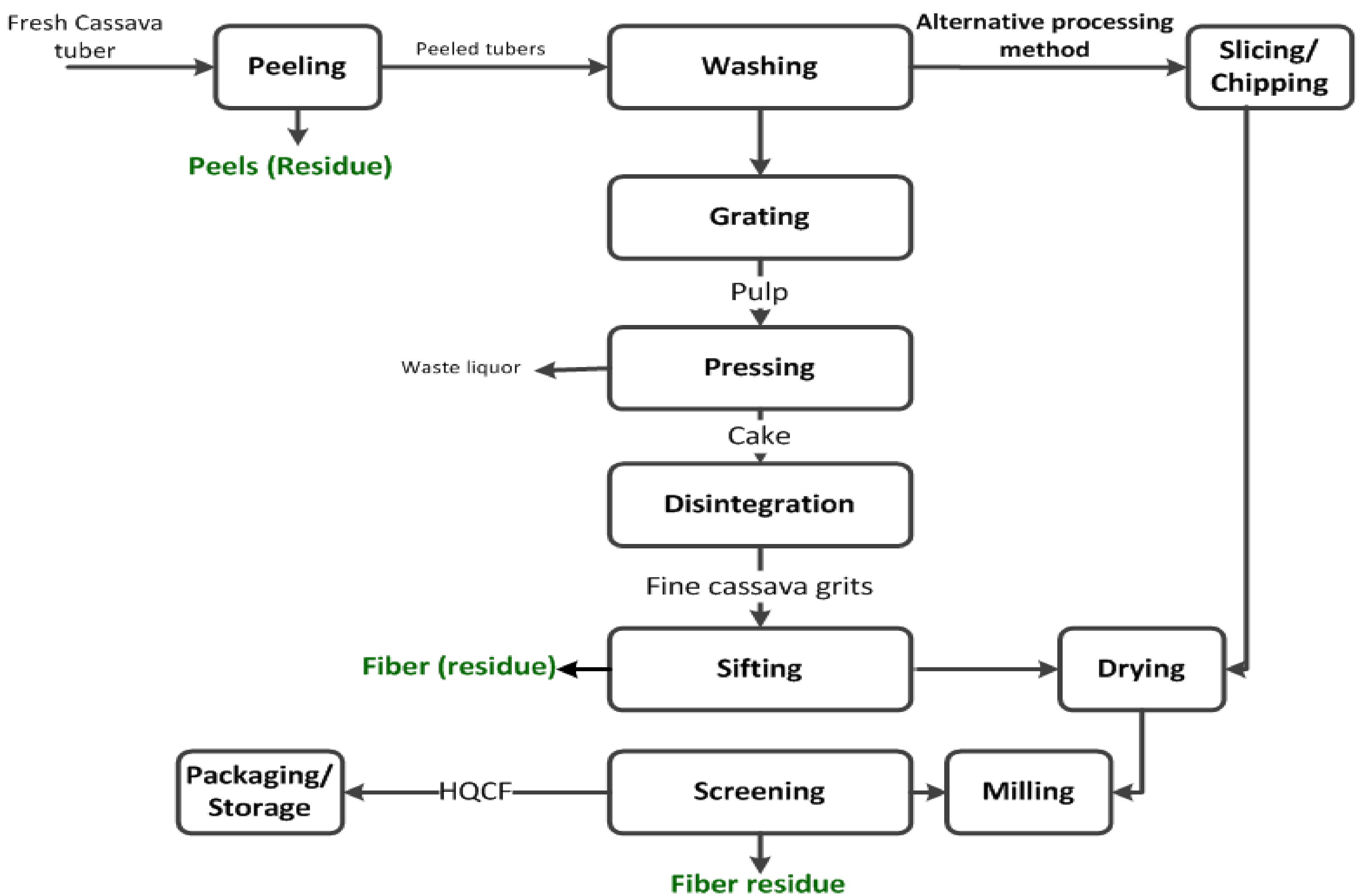
WP 3 Task 3.2: Techno-economic models; Case studies

Simplified Maize Flour (MF) process diagram



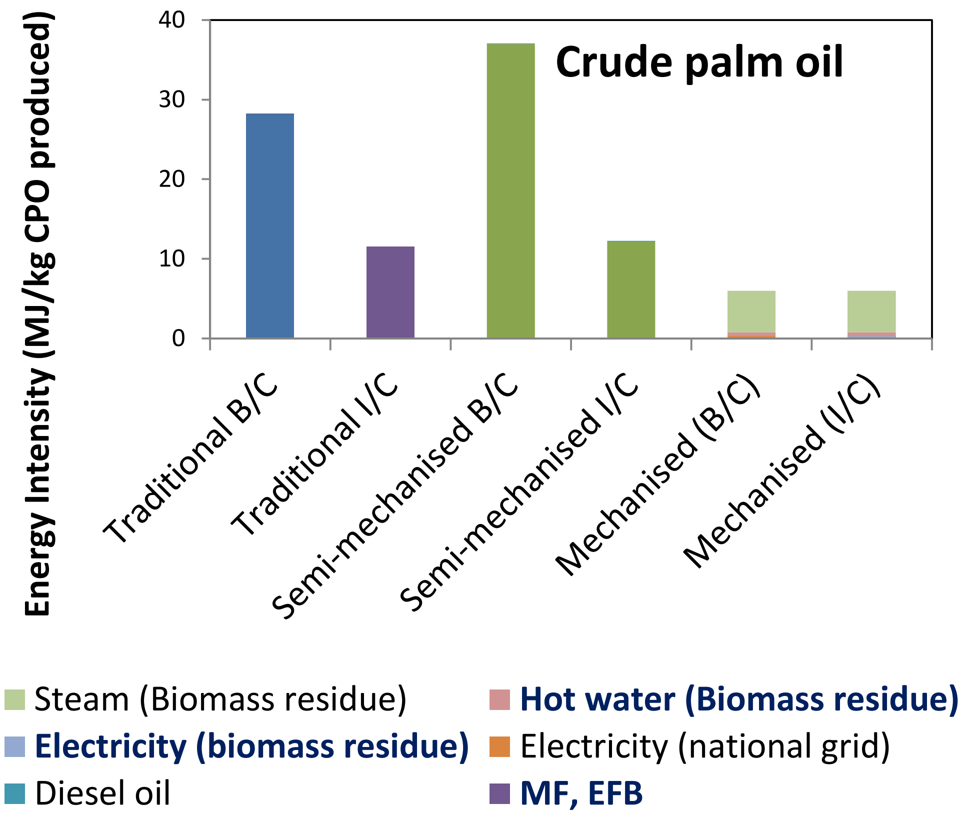
WP 3 Task 3.2: Techno-economic models; Case studies

Simplified Cassava Flour (CF) process diagram



WP 3 Task 3.2: Techno-economic models; Case studies

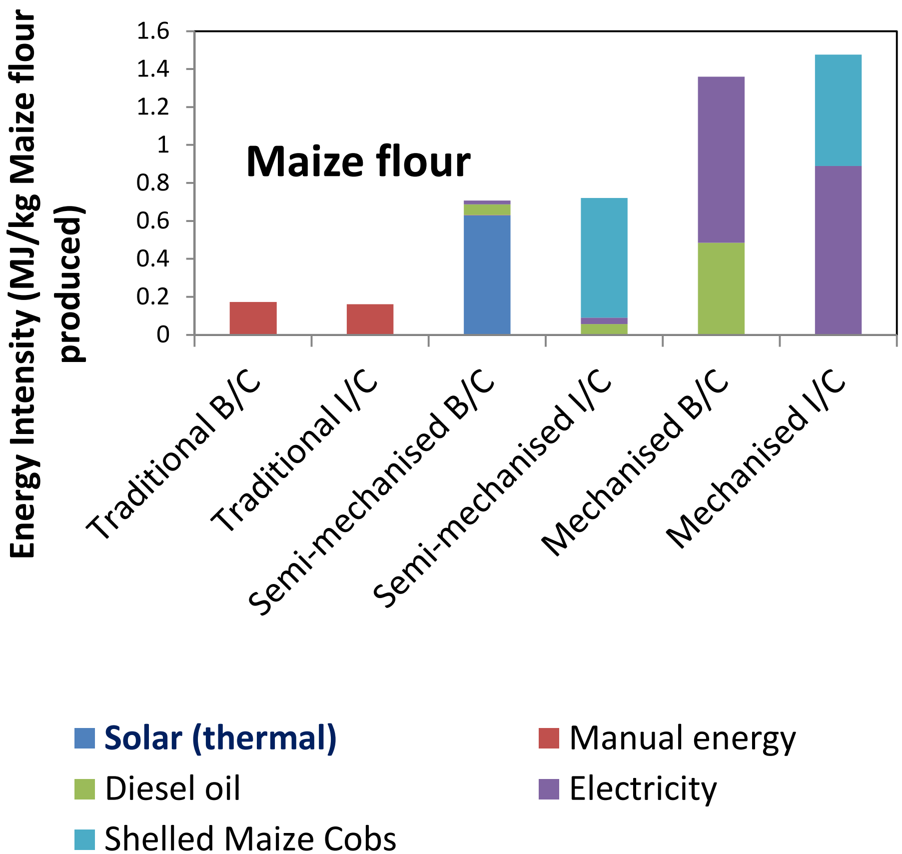
Energy-mix results :



- I/C - improved cook-stoves (efficiency of 30%) improves energy performance
- Mechanisation has inconsistent impact on process energy demands
- Solid biomass residues are adequate for traditional, semi- and mechanised I/C process energy

WP 3 Task 3.2: Techno-economic models; Case studies

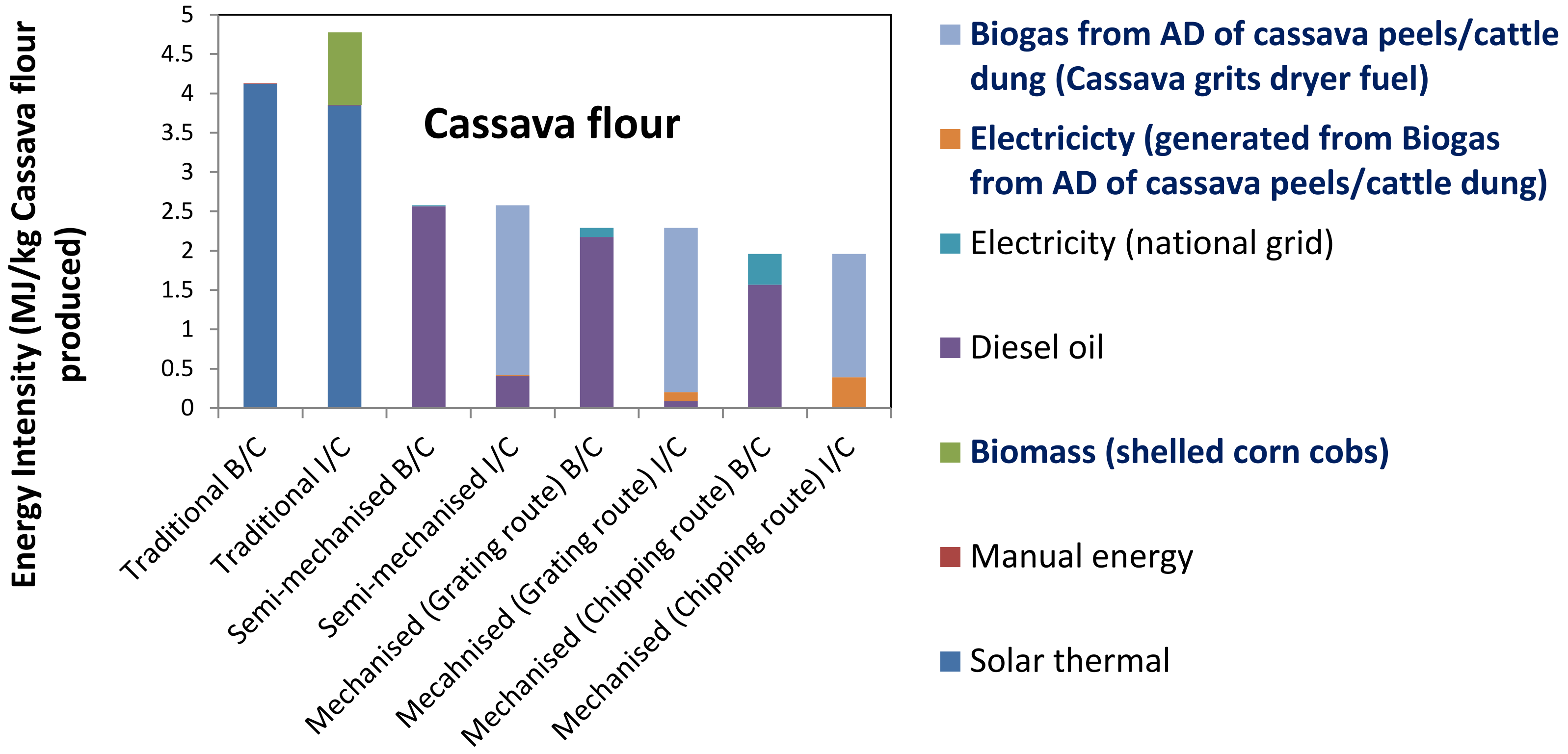
Energy-mix results :



- Traditional process – manual energy dominated; less room for renewable integration due to technology constraints e.g. mortar/pestle for pounding maize
- Mechanisation increases process energy demands
- Cobs suffix for dryer fuelling purposes in semi- and mechanised levels

WP 3 Task 3.2: Techno-economic models; Case studies

Energy-mix results :



- Mechanisation decreases process energy demands
- Biogas from peels/cattle dung suffix for semi- and mechanised process electricity/dryer fuel

WP 3 Task 3.2: Techno-economic models; Case studies

Economic results :

Crude palm oil models:

Parameter	Traditional		Semi-Mechanised		Mechanised	
	B/C	I/C	B/C	I/C	B/C	I/C
IRR (%)	-	-	-	143	47.23	40.57
Required CPO prices for economic viability ($/ton)	950	856	810	500	500	569

NB: Economic evaluations considered financing terms of 60% loan (interest rate of 24%) and 40% equity (interest rate of 40%), thus expected Internal Rate of Return (IRR) for viability = weighted discount rate = 30%

Key: (yellow) - economically viable, (red) - economically unviable

- Renewable energy (RE)/improved cook-stove **improves economics for semi-mechanised**
- RE (biomass residue) integration still makes **mechanised process economically viable**.
- Compare expected prices of CPO for economic viability to prevailing price of **$710/ton**

WP 3 Task 3.2: Techno-economic models; Case studies

Economic results :

Maize flour models:

Parameters	Traditional		Semi-Mechanised		Mechanised	
	B/C	I/C	B/C	I/C	B/C	I/C
IRR (%)	-	-	-	18.82	-	132.83
Required MF prices for economic viability ($/ton)	904.5	828	689	578	-	426

NB: Economic evaluations considered financing terms of 60% loan (interest rate of 24%) and 40% equity (interest rate of 40%), thus expected Internal Rate of Return (IRR) for viability = weighted discount rate = 30%

Key: (yellow) - economically viable; (red) - economically unviable; (green) - economically promising

- Renewable energy integration (cobs as dryer fuel) **improves economics for semi-mechanised**, makes the **mechanised process economically viable**.
- Compare expected MF prices (for economic viability) to prevailing wheat flour price of **$560/ton**

WP 3 Task 3.2: Techno-economic models; Case studies

Economic results :

Cassava flour models:

Parameters	Traditional		Semi-Mechanised		Mechanised (Grating route)		Mechanised (Chipping route)	
	B/C	I/C	B/C	I/C	B/C	I/C	B/C	I/C
IRR (%)	16.26	24	-	-	-	-	36.32	24.84
Required CF prices economic viability ($/ton)	579	566	646	656	681	630	551	571

NB: Economic evaluations considered financing terms of 60% loan (interest rate of 24%) and 40% equity (interest rate of 40%), thus expected Internal Rate of Return (IRR) for viability = weighted discount rate = 30%

Key: yellow - economically viable; red - economically unviable; green - economically promising

- Only mechanised-chipping B/C meets expected IRR of 30%.
- Traditional processes economically promising, **could suffice under soft loan/grant conditions**; compare expected CF prices (for economic viability) to wheat flour price of **$560/ton.**
- Biogas from peels/cattle dung has **negative economic impacts on mechanised-chipping process;** maize cobs as dryer fuel (during rainy season) **improves production capacity and economics in traditional level.**

WP 3 Task 3.2: Techno-economic models; Case studies

Conclusions:

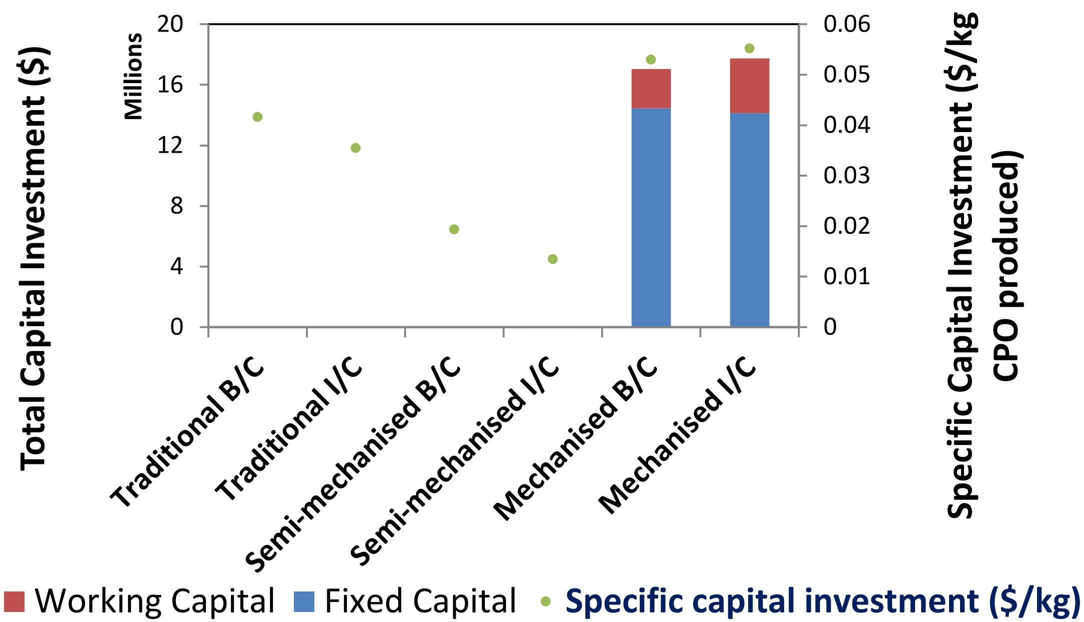
- Increasing modern energy (diesel and electricity) with increasing level of mechanization;
- Mechanisation impact on energy/economics inconsistent and specific to the food process conditions: depends on process equipment, energy/mass conversion efficiencies of equipment, and process energy forms.

WP3: Task 3.3

T3.3 Assess potential impact of changes on capital investment, job creation, income generation, decreased post-harvest losses and energy costs.

WP 3 T3.3: Potential impact of changes on capital investment, energy costs

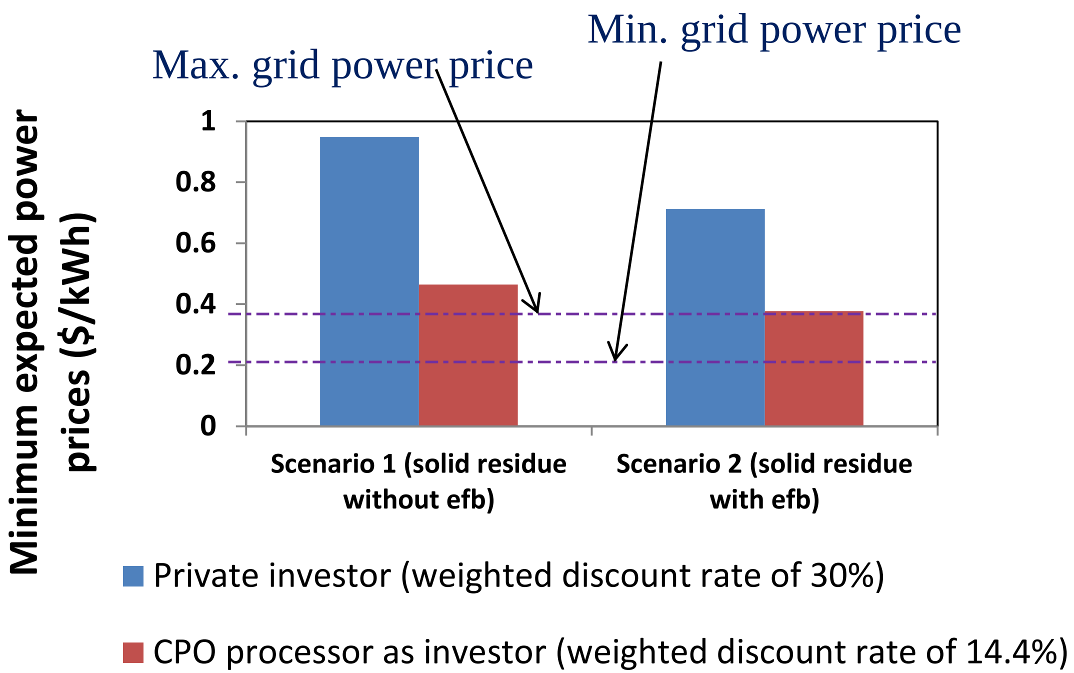
Changes on capital investment for CPO



- Specific capital investment (SCI) - is the capital investment per CPO produced ($/kg CPO)
- Compare SCI for B/C with corresponding I/C's; renewable energy/intervention in I/C processes **reduces capital investment**.

WP 3 T3.3: Potential impact of changes on capital investment, energy costs

Solid biomass residues to electricity/steam in CPO process

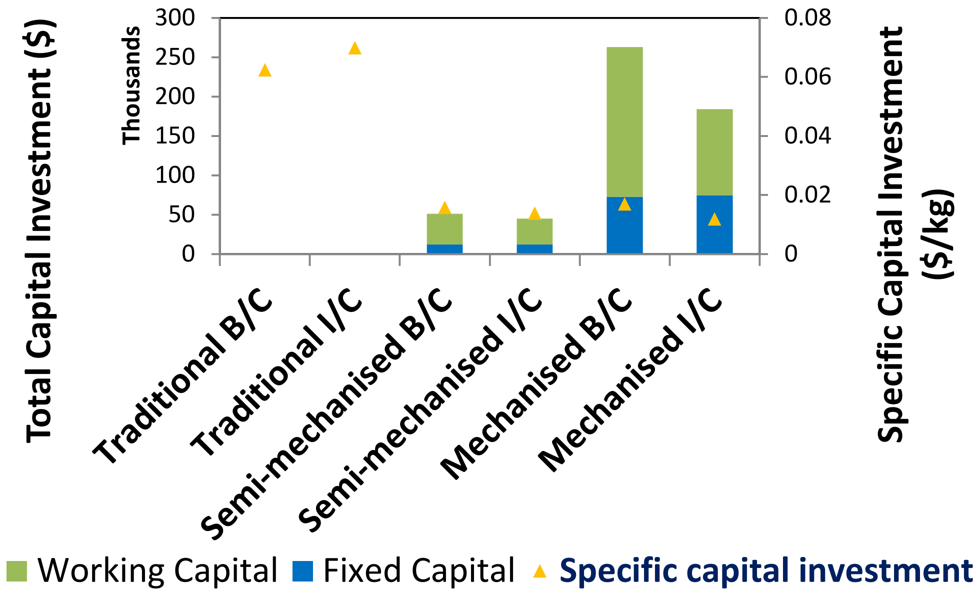


- Electricity from biomass residues generally expensive than grid prices (due to high interest rate on loans- 24%)

- Appreciable power price under CPO processor as investor (i.e. no profit expected on energy process ,but just enough cash flow to run the process and make the CPO process economically viable.

WP 3 T3.3: Potential impact of changes on capital investment, job creation, energy costs

Changes on capital investment for maize flour

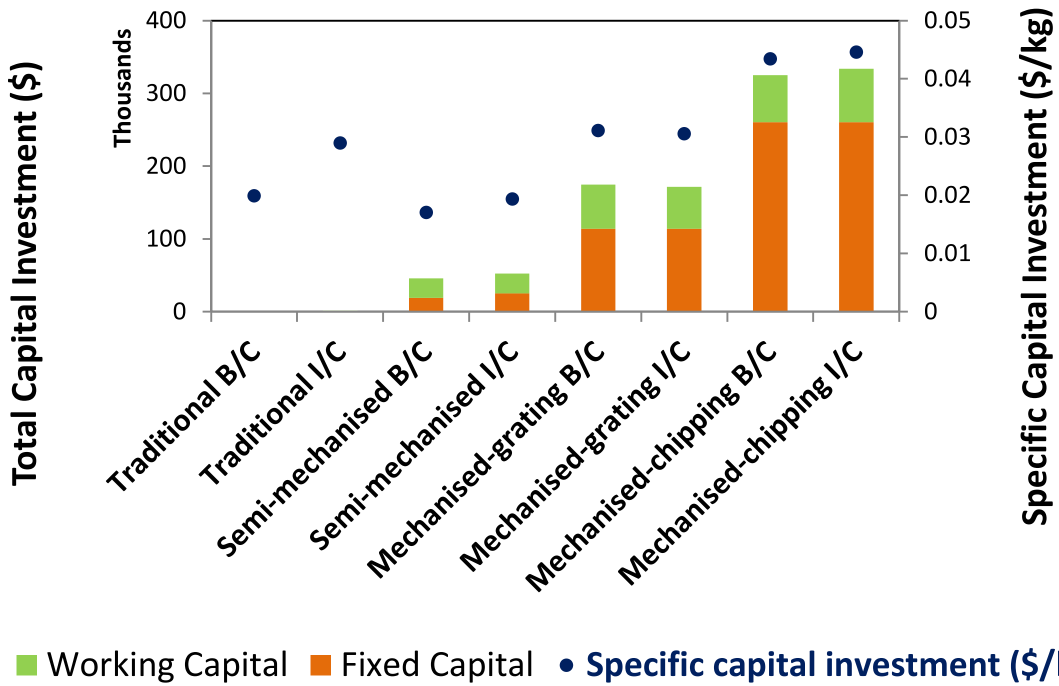


Specific capital investment (SCI) - is the capital investment per Maize flour produced ($/kg MF)

Compare SCI for B/C with corresponding I/C's: cobs as dryer fuel in I/C processes + sourcing feedstock directly from farmers (rather than buying from middlemen) **reduces capital investment in semi- and mechanised processes**.

WP 3 T3.3: Potential impact of changes on capital investment, job creation, energy costs

Changes on capital investment for cassava flour



Compare Specific Capital Investment for B/C with corresponding I/C's:

Cobs as dryer fuel in **traditional I/C process reduces investment cost**; biogas (peels/cattle dung) to electricity/dryer fuel generally **increases capital investment in semi- and mechanised processes**.

Conclusions

Crude palm oil

- Mechanisation **is economically beneficial at mechanised level**, bioenergy integration (solid residues) is **most beneficial in semi-mechanised/mechanised levels.**

Maize flour:

- Maize-cobs as dryer fuel is technically viable **but economically beneficial in the maximum mechanised level**.
- Mechanisation does **NOT** improve the economics. Feedstock supply chain (delivered price) is the major profitability determining factor.

Cassava flour

- Economic Impacts of mechanisation and bioenergy (AD of peels/cattle dung) are inconsistent; **traditional/mechanised chipping routes most promising**, while **semi-mechanised/mechanised grating routes not economically viable**.

Thus in general, investors must consider mechanisation/renewable energy integration on case-specific basis!

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