FINANCIAL AUTONOMY / PROFITABILITY

« SUSTAINABLE BIOENERGY » based on :

- *COMMUNITY AGROFORESTRY*
- *« MODERNIZATION » of productions CHARCOAL/CASAVA*

FIRST PART (energy optimization technique) :

« The Energy Optimisation of Carbonizations »

In the DRC : it is possible !

① Smoke Dépollution.

② Makala + 50%. ③ Free Heat.

SECOND PART :

④ Production of Casava flour for Breadmaking HQ.

Intégrated into «Modern Carbonization » (free heat)

« Best Available Technologies » Proposals based on :

- **The realities of agroforestry sites for "the source of sustainable wood energy"**
  - **→ Annual volume, density, wood size**
  - **→ Organization of wood supply logistics**
- **The objective of making the agroforestry model profitable through its own production and not through "climate subsidies"**
- **Sidenergie's technical proposal :**
  Semi-industrial carbonization with integration of cassava processing

  - **→ Flue gas depollution / Incineration → Heat production**
  - **→ Optimization of carbonization yield**
    Production : Charcoal (+50%) and Biochar (fertilizer, carbon sink)
  - **→ Use / Valorization of the production of heat from flue gases:**
    Drying of Cassava, fruits / Production of Cassava Flour for Breadmaking HQ
    Potential for "renewable biomass electricity" micro-production

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First part:

The modernization of carbonization

Fundamental prerequisite

In ideal carbonization (laboratory conditions with external heating)**:**

The initial calorific value of the wood is distributed
- Half in charcoal
- Half in the smoke

The fumes are composed of aerosols (droplets) of tars, other organic products and wood gases which are very good fuels in an incinerator/smoke scrubber.

Therefore, the thermal recovery/depollution of fumes is the essential operation of energy optimization techniques for the manufacture of charcoal.
This recovery of fumes is impossible in artisanal systems.

Analysis of the characteristics of the artisanal carbonization

THE FUNDAMENTAL ADVANTAGE OF ARTISANAL CARBONIZATION AND ITS INDUCED RISK

It makes it possible to organize production in millstones or pits directly near the site of the wood deposit, avoiding mechanized transport of wood and investment in kilns.

→ This is an important factor: Production without technical investments.
→ This allows workers to find a means of subsistence without investment.
→ But this encourages very large-scale informal production which is not intended nor the financial means to worry about the sustainability of the wood resource. (except of IBI Village and the rare virtuous programs of sustainable wood energy plantations).

THE DISADVANTAGES OF ARTISANAL CARBONIZATION

1) Part of the wood is burned (wasted) to provide the heat needed for carbonization:
It is a technique with partial combustion of raw material wood.
→ So there is less wood available to produce charcoal.

2) The other part of the wood makes charcoal.
→ But 10% of the charcoal is lost on the carbonization site in the form of fines and incuits which cannot be recovered.

3) Flue gases rich in calorific value are released/lost to the atmosphere:
→ **The fumes are "very polluting"** for the environment and they are toxic to health workers and neighbors.
→ **"LOSS of half of the energy potential of the wood produced by the agroforestry site!! »**

▪ The mécanism of the wood carbonization reaction

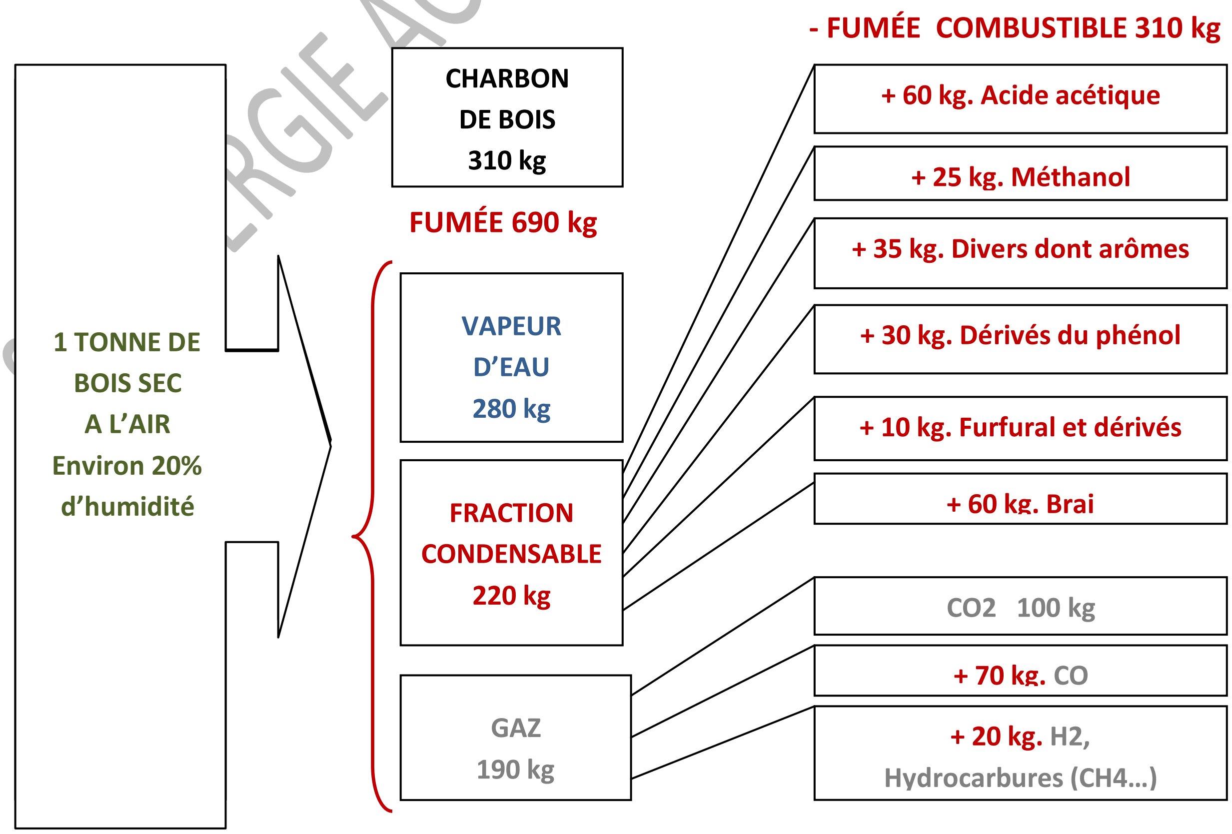
CARBONIZATION FUMES

- The transformation of wood into charcoal is as old as fire.
- The charcoal makers knew how to produce charcoal but also all kinds of chemical products from smoke: acetic acid, tannins, strawberry and raspberry aromas, liquorice, etc., tar (coaltar, Norwegian pitch, wood creosote, etc.) for protection marine and construction timber. This wood chemistry requires very good mastery of the carbonization process and process and chemical engineering techniques to recover the fumes.
- Researchers (eg CIRAD) have studied the reactions (behavior) of wood subjected to a heating operation as well as the composition and characteristics of smoke.
  It is the result of their work and the experience of the charcoal makers who are exploited to enormously improve the carbonizations, using the minimum of technical equipment.

The majority of the chemicals contained in the fumes are very good fuels, except for water vapor and CO_2.
The goal is to burn the fumes in a "Smoke Scrubber/Incinerator".

This combustion has very interesting results: Flue gas depollution + Thermal energy
→ *A lot of heat produced: That is half of the initial calorific value of wood (PCI)*
→ *And clean atmospheric emissions*: H_2O and CO_2 with proper management of flue gas combustion according to BAT requirements. "Best Available Technologies".

The « combustion of fumes » is therefore the method for « dépollution / sanitation » polluting atmospheric emissions from the charcoal production.



HOW DOES WOOD BECOME CHARCOAL ? CARBONIZATION PHASES AND THEIR FUMES

This paragraph does not go into the details of the thermal transformation of the main compounds of wood (lignin, cellulose and hemicellulose) but it is interested in the general reaction of wood subjected to a rise in temperature.
The figures for temperatures and thermal requirements used are the orders of magnitude that interest us to design an optimized process, they are not looking for precision.
(Cf. Biomass energy guide, pages 151 … ACADEMIA edition. Louvain la neuve Belgium)

Phase 1 of carbonization : from ambiant température à 250°c → from raw wood to roasted wood

Large need for heat for this carbonization phase : endothermic phase

Smoke characteristics : strong release mixed with water vapour, bad fuel

→ Significant need for heat in phase 1 of carbonization. The reaction is "endothermic". It requires a lot of heat.
The need corresponds to approximately 2 MW for 3 hours for 10 tonnes of raw wood at 30% humidity.
The thermal requirement is high at the beginning then decreases to become zero at 250°C

→ The fumes from Phase 1 of carbonization. Release of non-combustible fumes at first, made up of a majority of water vapour, then increasingly combustible.
The fumes are however polluting because they contain a lot of organic acids.
The calorific value of the flue gases is nil at the start, their "cracking/purification" in the purifier requires external energy supplied by a support burner or by mixing with highly combustible fumes from phase 2 from another furnace [See next paragraph], then the fumes begin to self-ignite and purify themselves spontaneously when the wood is around 220/250°C.

Phase 2 of carbonization : from 250°c to 350°c → roasted woos to charcoal

The carbonization furnace self-produces its own heat for carbonization: exothermic phase

Smoke characteristics: very strong release, very good fuel

It is during this phase that the carbon compounds, with a high energy content and very polluting, leave the wood in the form of smoke.
These are the most abundant gaseous effluents of the entire carbonization cycle.

A clear exothermic reaction naturally occurs which rapidly raises the temperature of the oven to 350°C without any external energy input.
It is during this phase that the carbon compounds, with a high energy content and very polluting, leave the wood in the form of smoke.
These are the most abundant gaseous effluents of the entire carbonization cycle.

→ No need for heat for the carbonisation phase 2. *The réaction is « Exothermic » : It requires no heat input.*

→ The fumes from the carbinization phase 2 *are very abundant, very combustible and very polluting.*

The fumes from the exothermic phase constitute the majority of the calorific value of the fumes from the entire carbonization cycle, i.e. approximately 40% of the thermal potential of the raw material wood.

It is on the exploitation and control of the characteristics of the exothermic phase that technological advances in improving the performance of carbonisations are based.

The use/valorization of the very large quantity of heat produced by the purification of fumes from the exothermic phase:
ALLOWS THE ENTIRE CARBONIZATION CYCLE TO BE LARGELY EXCESSIVE IN ENERGY

The use of the large quantity of heat produced by the purification/incineration of the self-combustible fumes of this phase ② allows:

- **To provide heat for the carbonizations of the other ovens started in relay. Therefore to avoid the combustion of part of the wood → Improved yields.**
- **To purify the fumes of the other furnaces started in relay → Depollution.**
- **To supply energy to a nearby workshop, which consumes a lot of heat.**
  - **→ Free heat: Safe drying of cassava processing.**
  - **→ Potential for self-production of renewable biomass electricity. (Techniques begin to develop)**

Phase ③ of carbonization → from 350°c to the end of carbonization (between 400 and 500°) depending on the quality of charcoal sought

Slightly endothermic phase
Smoke characteristics: low emission, very good fuel

- This phase ③ requires a slight heat input, 10 times less than phase ①.
- Smoke releases (pollutants) are much less intense but they also have a high calorific value. They support the long-term availability of heat from the smoke purifier.

▪ Principle of optimized carbonization

THE OBJECTIVE

Use the large quantity of heat produced by the purification of fumes from the exothermic phases ② of carbonizations to provide the heat necessary for the entire production system: "Carbonization + Depollution + Provision of heat for the drying workshop cassava". Optimization of the initial PCI of wood → coal 45% + smoke heat 45% - Ɛ % losses.

THE DIFFICULTY

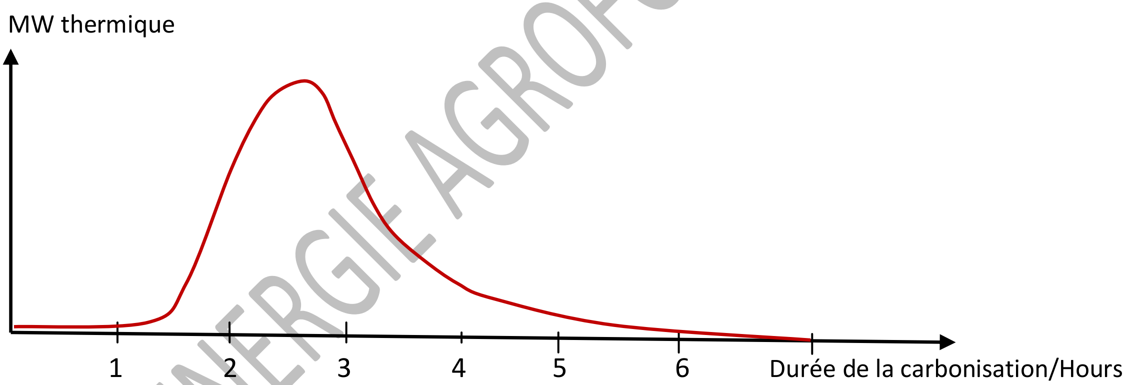
During the carbonization of a kiln, this large amount of flue gas heat is not continuously available. It is provided intensely and superabundantly only for a relatively short time which may be 20-30% of the total kiln carbonization time.
This duration varies according to the size and species of the wood to be carbonized as well as the carbonization process.

THE SOLUTION

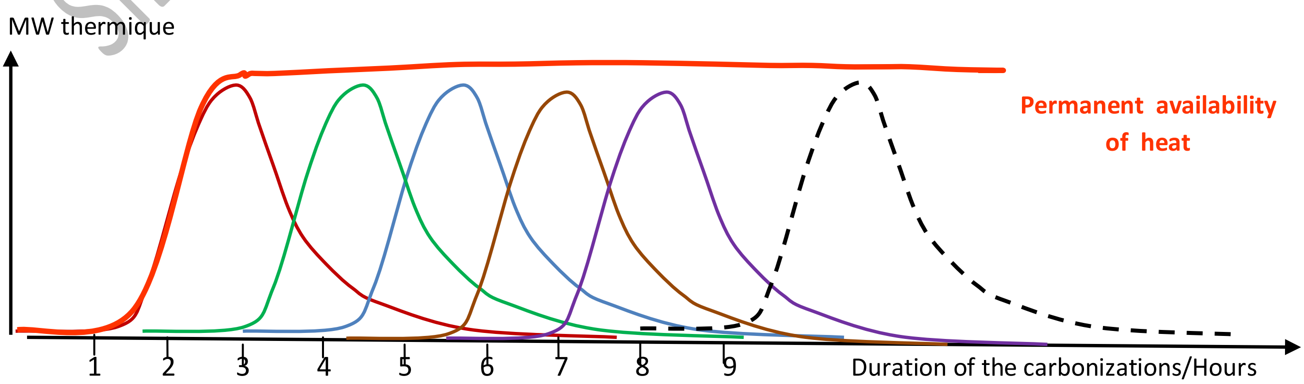
In order to be able to permanently have heat in the smoke purifier, the releases of the exothermic phases of each furnace must take turns.
It is therefore necessary that several furnaces be put into service successively.
Depending on the type of wood, therefore depending on the duration of the carbonizations of each oven, the management of the smoke purifier is optimal from 4 or 5 ovens which operate in relay.

EXAMPLE

For 1 kiln → Visualization of the peak quantity of heat available in the smoke incinerator



For 5 Relay kilns → Regularity of the quantity of heat available in the smoke incinerator



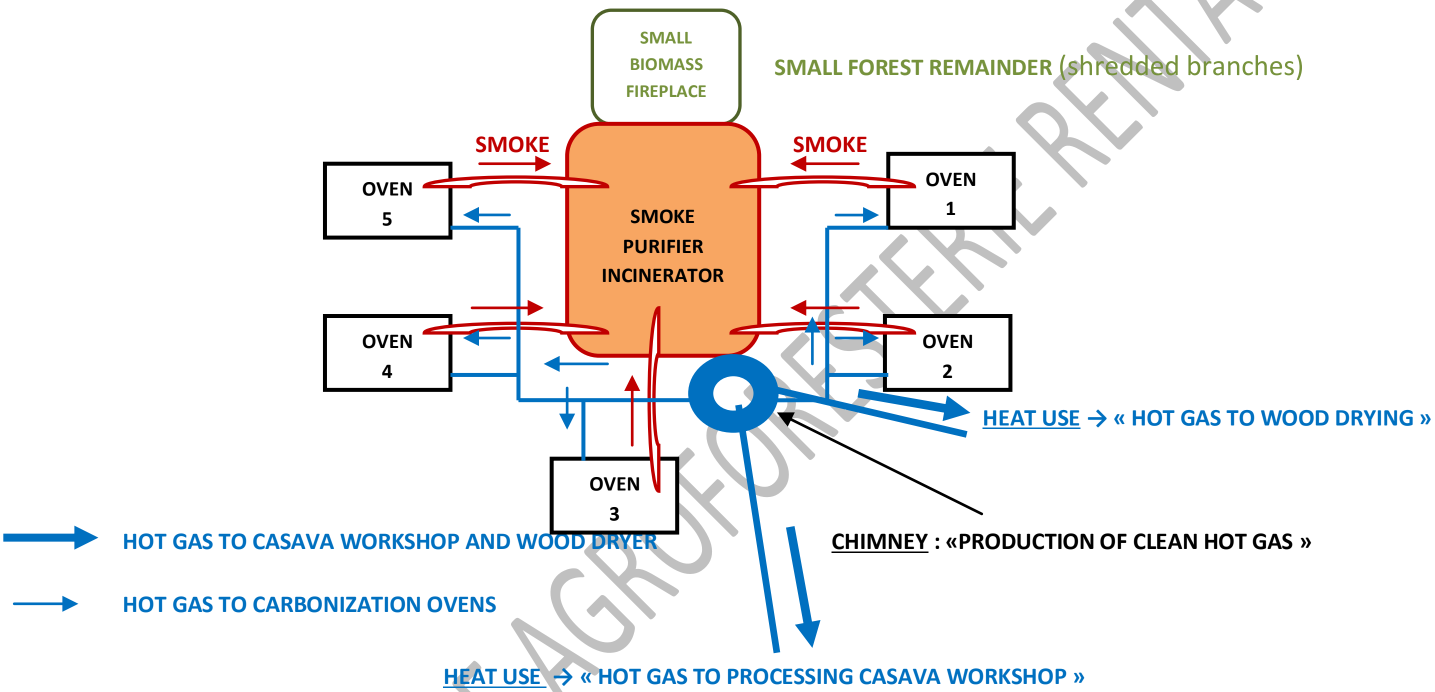
Conclusion on the technical concept

A central smoke purifier powered by the fumes from a battery of several furnaces which carbonize in relay:

→ Permanently produces a large amount of heat for carbonizations and for peripheral uses. (For example for drying in a cassava processing workshop, for pre-drying raw wood and for other potentialities).

→ Produces Charcoal and Biochar with a very good yield, with the desired qualities.

INSTALLATION PRINCIPLE



→ The biomass fire operates at high speed at the start of the cycle to crack/purify the fumes from the beginning of the carbonization of the first furnace, then it remains on the back burner of support because the fumes from the ovens are the fuel for the rest of the carbonization cycle.

→ Each kiln contains a 10 m³ container/basket, i.e. around 4 tonnes of wood. The containers are loaded onto the timber cutting plot and transported by tractor at the carbonization site.

→ At the end of the carbonization of the kiln, the container is removed from the oven hot then it is placed under a choke box. A new carbonization can start immediately. (2 days in a choke box then 1 day of stabilization in the open air against the risk of fire).

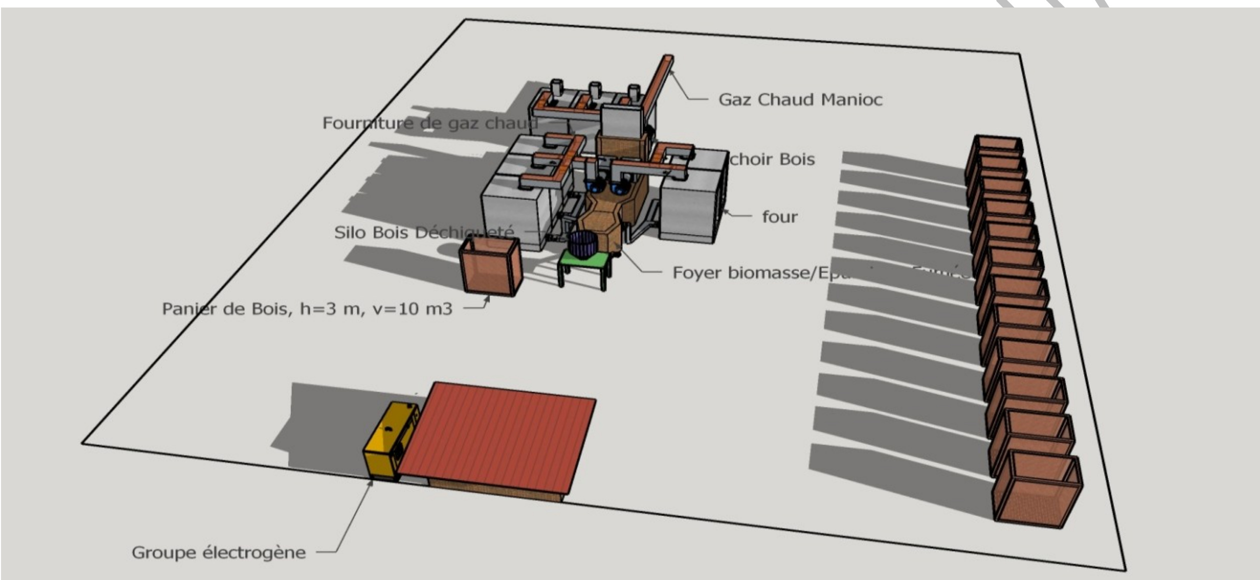
→ The significant excess heat from the flue gas scrubber is available to supply the uses drying: the cassava processing workshop, the pre-drying of raw wood, etc., electricity.

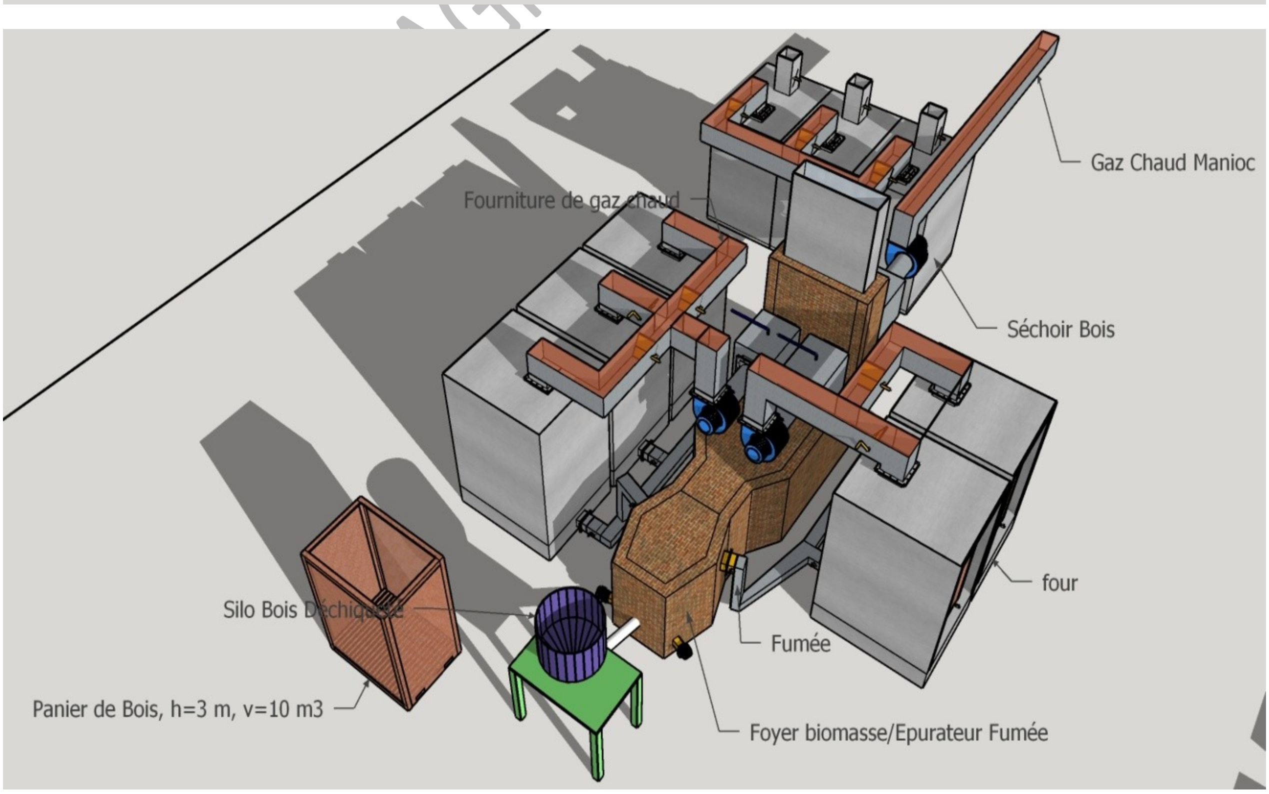
THE PROCESS : Hot gas circulation furnaces, optimized "charcoal + free heat" productions.
« Smoke depollution and energy recovery of smoke"

Industrial carbonization unit adapted to agroforestry units of 2500 ha.
Maximum capacity: 18,000 t/year of wood, 4,500 t/year of charcoal and 675 t/year of cassava flour

- 5 carbonization ovens for 10 m3 wooden containers/baskets, 1 container/oven.
- 1 central smoke purifier/incinerator, equipped with a biomass hearth (residues from wood cuttings)
- 3 condensation pre-drying enclosures, wood (wood dryer).
- Many wood containers/baskets for loading in the forest, for pre-drying, for carbonizing, for cooling under a choke box, for stabilization in the open air, for buffer wood stock, etc.

Carbonisation Kilns SIDENERGIE (Dépollution/ Thermic Valorisation of smoke). 05/2022
This process has been operating since 1994 in intensive industrial use, it is duplicated in 6 units.





▪ The socio-environnemental and climatic benefits of optimized carbonisation

Improved working conditions for villagers.

→ Stable and well-paid jobs. Acquisition of technical skills.
→ Good sanitary working conditions (elimination of fumes).
→ Women benefit from improved production of biochar and cassava.

Environmental benefits.

→ Elimination of atmospheric pollution.
→ Saving of raw material wood by improving carbonization yields.
→ The fundamental characteristic of the project comes from the sustainable management of the deposit raw material wood: Each charred tree is replanted → at each rotation additionally the soil is increasingly fertilized and the biotope is improved.
The flora and fauna biodiversity of the carbon sink flourishes in this forest context sustainable production.

Climate benefits.

→ Sustainable charcoal production: Reduction of deforestation, creation of a permanent forest carbon sink (afforestation + spreading of biochar fertilization).
→ Savings in oil equivalent (toe) by supplying sustainable biomass heat.
Ex: For 1t of dry wood, the thermal recovery of fumes saves 214 kg of oil equivalent (toe) or the equivalent of 690 kg of CO_2.
→ The incineration/depollution of fumes avoids the release of CH_4 (methane) which has a high global warming coefficient (21 times greater than CO_2).
This point is raised by the FAO in the 2017 study "The charcoal transition, Greening the charcoal value chain to mitigate climate change and improve livelihoods".

Economic interest: Revenues are doubled, agroforestry becomes profitable.
A private sector can develop in this sector of the Green Economy: "Sustainable Bioenergy"

→ Revenues from charcoal are increased by the good productivity of carbonizations.
→ The free use of a large quantity of heat improves the profitability of the processing of cassava and eliminates the current large production losses due poor traditional drying in the open air. Women's incomes are doubled.

Economic and environmental interests converge.
This sector has all the assets to develop in Central Africa.

"Sustainable Charcoal": Renewable Wood + Optimized Carbonization
An essential player in the panel of renewable energies of the future.

"We must learn to think about biomass energy in MWh equivalent and get out of a backward-looking vision (wood energy: dirty, inefficient, polluting) which is still too widespread, especially in the ruling classes". Cf. rapport final COMIFAC « EFBC 2040 » page 86.

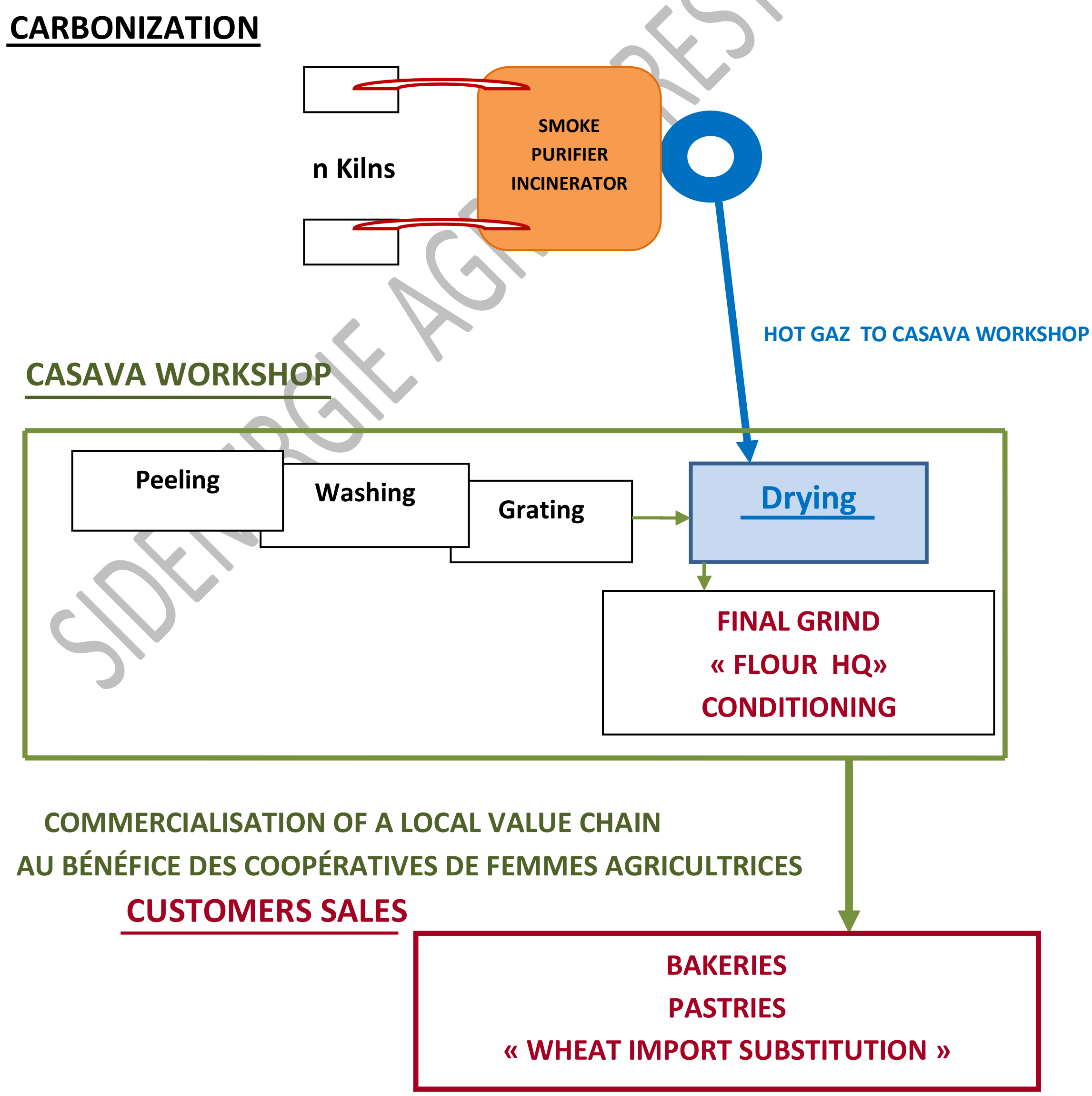
Second Part :

Intégration of modern carbonization into a New production of bread-making casava flour high quality

- **Prerequisite**

Cassava tubers rot when effective drying is not carried out within 12 hours after harvest. Currently the losses are very important with the uncertain natural drying.
An important objective of the project concerns the improvement of the cassava processing chain produced by women from the communities of the agro-forestry system.

The new availability of the large quantities of heat produced by the purification of carbonization fumes allows the innovative orientation of this free heat towards the "High Quality Cassava Flour sector for breadmaking" (bread, cakes, pasta).
Fossil energy consumption for major processing of cassava, gas or fuel, which is very costly in terms of supply and transport, is now avoided. It is replaced by “renewable biomass heat”.



FOR EACH COMMUNITY AGROFORESTERY SITE
UNIT INSTALLATION PROJECT
SEMI INDUSTRIAL INTÉGRATED « CHARCOAL / CASAVA »
- SOCIAL-ENVIRONNEMENTAL AND CLIMATE BENEFITS
- PROFITABITY

① GLOBAL INCOME STATEMENT for the minimum Configuration – 5 Ovens :
Domain 2500 ha : Planted 2250 ha, Places of life, Process, Équipment.
4500 t/year of charcoal and 675 t/year of casava flour (225 ha/year)

② GLOBAL INCOME STATEMENT for an optimized Configuration – 7 Ovens : french
Domain 3500 ha : Planted 3150 ha, Places of life, Process, Équipement.
5500 t/year of Charcoal and 945 t/ year of casava flour (315 ha/year)

③ GLOBAL INCOME STATEMENT for an optimized Configuration – 10 Ovens :
Domain 5000 ha : Planted 4500 ha, Places of life, Process, Équipement.
9000 t/year of Charcoal and 1350 t/an de Farine de Manioc (450 ha/year)

Project Note

Community agroforestry with cassava intercropping, combined with:

- **A proven process for energy optimization of wood carbonization.**
    - **Improved productivity of charcoal, biochar (quantity and quality), (Recipe improvement).**
    - **Dépollution / Incinération of fumes.**
    - **Production / Provision of large quantities of heat energy.**
- **A méchanised casava processing workshop, powered by the heat generated by the carbonization unit.**
    - **Elimination of large quantities of losses/rotting of harvested tubers, thank the new regularity of the drying operation.**
      (Efficiency and independence of hot air drying with respect to the vagaries of natural drying in the open air).
    - **Production of « High Quality » bread-making casava flour, (Improvement of recipes).**

▪ Current situation and objectives

• The concept of community agroforestry producing sustainable fuelwood and cassava is mature and sustainable. The pioneer sites (15 years of scientific research) of Mampu, IBI Village, Ntsio on the Bateke plateaus have developed the technical itineraries, which are now applicable.
A model based on 2500 ha generates many socio-environmental and economic benefits:
- 50 permanent jobs and the installation of workers' families: from 250 to 300 people.
- Production of sustainable energy wood, 18,000 t/year of raw material wood for makala.
- **“Traditional carbonization with low yield, 3000 t/year of charcoal” (makala.)**
- Artisanal processing and marketing of cassava for the benefit of village women, with many losses.
- Production and marketing of acacia honey.
- Crops (self-consumption) food crops, orchards and livestock: poultry, sheep, pigs.
- Replanting of native forest species, islands of diversification of woody species.
- Sustainable soil fertilization (wood and leaf forest litter, slurry, biochar).
- Permanent carbon sink due to the annual exploitation/replanting of the forest.
- Buffer zone for the protection of neighboring gallery forests and possibly neighboring natural parks.
- Carpentry workshop.
- School, dispensary, village cooperatives.

• Increasing the surface area of agroforestry plantations producing “Sustainable Energy Wood” is a strategic objective of the DRC.
For this, **it is necessary for the sector to achieve financial autonomy** without depending on “international climate aid”: The profitability of the two main commercial resources must be improved.
Charcoal and cassava are currently produced by small-scale producers with low yields and subject to great difficulties during the rainy season. Half of the energy power of the wood is lost.

• Sidmarine Sas/Sidénergie, a former charcoal manufacturer in France, proposes to implement an innovative and adapted carbonization process on existing agroforestry sites or those to be created:
- Hot gas circulation furnace process (developed by CIRAD and Sidénergie)
- With smoke depollution/incineration equipment and the induced production of a large quantity of heat energy to be recovered in the cassava processing workshop.

This kiln principle worked for 30 years at Sidénergie SA (4500 t/year of charcoal). Since 2012, this process has been used by Carbonex, which recovers thermal energy from flue gas purification by cogenerating electricity: 10,000 t/year of charcoal and 3MW of sustainable biomass electricity. This process was co-opted as a low-carbon demonstrator at COP 21 and 23 and duplicated 5 times in France as part of calls for tenders from the Energy Regulation Commission (CRE) to develop renewable biomass electricity in France.

Sidénergie following several missions in this field carried out in Central Africa (Ex. COMIFAC / PPECF C166 and C177 studies) proposes to optimize the production of charcoal and cassava by setting up a semi-industrial oven whose heat resulting from the depollution/incineration of fumes will make it possible to supply in all seasons the large quantity of heat necessary for the production of charcoal and for the drying operation of cassava processing.

▪ Project interests

The qualification of the project as "semi-industrial" is explained by the fact that the operations of the two value chains, charcoal and cassava, **retain the current mode of operation which is very labor-intensive for all agricultural operations and forests**.
Only certain processing operations (carbonization and cassava workshop) will be mechanized, without loss of jobs.
The technical equipment is basic and well known in the DRC: Fans for the transit of gaseous fluids, forklifts and tractor-trailers for handling.
Lots of equipment can be made by local businesses.

• Clean atmospheric emissions, compliant with European regulatory standards.

• Good sanitary conditions for the workers and the neighborhood.

• The wages of village producers increase thanks to the increase in the yields of marketed productions: E.g. doubling of income for cassava producers.

• All wood supply jobs are retained: planting/maintenance, logging, limbing, hauling, loading the carbonization system.

• The number of jobs on the carbonization site remains identical to the current context of artisanal carbonization.
This new form of permanent employment will require an improvement in qualifications.

• Increase in charcoal revenue due to improved productivity.
The high availability of heat from the purification/incineration of fumes allows efficient pre-drying of the wood raw material.
Production becomes independent of the rainy season which stops artisanal production. Marketing in the rainy season becomes possible with a strong improvement in the profit margin.
CIRADD has initiated a “Sustainable Charcoal Label/Certification process”. Ultimately, this certification will also improve the profit margin of IBI Village's sustainable makala.

• The availability of the large quantity of heat resulting from the depollution/incineration of fumes allows the integrated creation of a cassava processing unit which will be independent of the weather conditions of the heavy rain seasons.
This new technical context will make it possible to avoid significant losses due to the current recurring rotting of batches that do not have good sunny conditions for drying.

• The new availability of large quantities of heat opens up accessibility to a new form of production with better added value for cassava: “high quality bread flour”.
This new locally produced product (creating jobs) is of great national interest for its potential as a substitute for the current widespread import of wheat flour.

• The internal and free production of large quantities of "sustainable biomass heat" necessary for the cassava drying operation will replace the consumption of costly fossil energy and the random supply of conventional industrial processing workshops.

• This semi-industrial center will include maintenance workshops that will benefit the entire site and its living areas: mechanics, welding, electricity, small metal construction.

• Revenues, significantly improved, will contribute to strengthening the economic sustainability of all activities, workers' incomes and financing the objective of extending planted agroforestry areas which is currently on stand-by.

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Note on the production capacity of the carbonization unit

Carbonization technology with permanent flue gas purification requires at least supplying the flue gas purifier/purifier with at least 5 carbonization chambers (furnaces) which operate as a relay. (See previous technical note).
Each oven carbonizes 4 tons of wood in 8 hours, i.e. 3 carbonizations/day.

FOR A CARBONIZATION UNIT OF 5 FURNACES (Minimum Technical configuration of the Process).

- **The nominal (maximum) capacity of the carbonization unit is 15 kilns/day (à 4 tonnes wood/oven) for 300 days.**
- **Or 14 ovens/day for 300 days/year.**

CAS ① : i.e.a maximum carbonization capacity of de 18 000 t wood/year → 4500 t/year of charcoal

IT NEEDS A SITE OF 2500 ha = 2250 ha PLANTED + FIREBREAKS + RAODS + BUILDINGS + GARDENS +ORCHARDS WITH AN EXPLOITATION/REPLANTATION OF 225 ha/year

This is a conservative assumption (25%): 80 t/ha of carbonizable dry wood over a rotation of 10 years, Whereas CIRAD studies in Mampu determined 107 t/year of carbonizable dry wood over 10 years.

Note : 1 kiln consumes 3600 t/year of wood for a production of 900 t/year of charcoal
1 kiln needs the exploitation/replanting of 45 ha/year (3600 t = 80 t/ha x 45 ha)
i.e. a total area of growing plantation en croissance of 450 ha

Income statement ① : 2500 ha, 5 Ovens, 4500 t/year makala, 675 t/year flour

Minimum requirement

Plantation Investments : 2250 ha planted on a 2500 ha estate

- In this case of an integrated “Agroforestry planting site/Makala/Cassava production” unit, tractors/trailers are used for all activities: transport of seedlings, planting, maintenance + transport of raw material wood to carbonization.
  For simplicity, all of their depreciation, consumables and maintenance are allocated to the semi-industrial makala/cassava production unit.
  So these uses of machinery do not appear in the planting item.
- Labor for planting and maintaining plantations is paid by the cassava purchase item ($105/t of tubers) to village associations.
  Therefore, the planting/maintenance payroll does not appear in the planting item.

Usually the cost price of a mature plantation under the conditions of the Bateke Plateaux ranges from $2,000/ha for Mampu to $1,500/ha for IBI Village.

Here, the important operations of planting seedlings and maintaining the plantation (machinery and labour) are supported by makala and cassava production.
→ So the remaining plantation investment only includes nurseries and plot preparation (largely mechanical clearing, harrowing, firebreaks, etc.)

→ We take a remaining planting investment of $1,100/ha in reference to the researchers' studies and the specificities of the project.

Plantation investment to be made over 5 to 8 years: 2,250 ha x $1,100/ha = $2,475,000

This investment is depreciated in the “Cost of wood raw material” item at $13.75/t.

Investments in semi-industrial Makala/Cassava production

- Carbonization plant (5 ovens) = $1,000,000 depreciable over 15 years → $ 66,667/year
- Cassava workshop = $250,000 depreciable over 10 years → $ 25,000/year
- 6 trailer tractors = $300,000 depreciable over 7 years → $ 42,857/year
- 4 forklifts (2x12 t + 2 x3.5 t) = $350,000 depreciable over 7 years → $ 50,000/year
- 2 wood chippers (biomass fireplace) = $30,000 depreciable over 7 years → $ 4,286/year
- Excavation of the production site = $300,000 depreciable over 20 years → $ 15,000/year
  Production area 70 x 100 m
  Stabilization, stonework, waterproofing, tar, concrete
- Roads = $300,000 depreciable over 20 years → $ 15,000/year
- Technical buildings = $550,000 depreciable over 20 years → $ 27,500/year
  Offices, changing rooms/showers, workshops, store,
  Charcoal packaging storage, Cassava workshop buildings
- Social buildings = $400,000 depreciable over 20 years → $ 20,000/year
  Village houses, school, dispensary, meeting/leisure center
- Water = $250,000 depreciable over 20 years → $ 12,500/year
- Electricity (electro unit + network) = $100,000 depreciable over 20 years → $ 5,000/year
- Transport, customs = $150,000 depreciable over 15 years → $ 10,000/year
- Engineering = $400,000 depreciable over 12 years → $ 33,333/year
- Miscellaneous, contingencies = $200,000 depreciable over 12 years → $ 16,667/year

Total production unit investments + social amenities = $4,580,000
Total depreciation $343,810/year

Overall investment (Production Unit 5 Ovens + Plantation + living spaces) = $7,055,000

- ## Overall provisional income statement of the whole (5 ovens):
« Agroforestry plantation + Modernized Makala/Casava productions »

Total carbonization unit expenses, → $ 1,185,810/year
of the plantation and the whole place of life.

- **Tonnage of wood available and carbonization cycles → 18,000 t/year, 4 t/kiln, 14 kilns/day, 320 days**
  - Area exploited = 225 hectares/year
  - Productivity of the plantation = 80 tons/hectare

- **Cost of raw material wood delivered to the factory → $29.50/t x 18,000 t/year → $ 531,000/year**
  - Nursery costs, planting preparation = $1100/ha, 80 t/ha → $ 13.75/t
  - Cost of logging, skidding, loading = $900/ha → $ 11.25/t
  - Transport to the carbonization site ($3/km x 6 km for 4 t/enclosure) → $ 4.5/t
  (6 km = an average shuttle of 1 return trip of 3 + 3 km for 4 t of wood) x 12 shuttles/day

- **Amortizations ……………………………………………………………… → $ 343,810/year**

- **Maintenance, technical consumables, water, packaging bags → $ 110,000/year**

- **Diesel ……………………………………………………………………………………… → $ 139,800/year**
  (Average approach: 5 gears x 5 l/h x 8 hrs/d x 320 d x $1.2/l = $76,800/year)
  (Genset: 6 l/h x 24 h/d x 365 d x $1.2/l = $63,000/year)

- **Wages ……………………………………………………………………………… → $ 61,200/year**
  - 15 forklift carbonizers x $4/day x 30 days/month x 12 months → $ 21,600/year
  - 2 technicians x $450/month → $ 10,800/year
  - 1 + 1 site managers x $600/month → $ 14,400/year
  - 1 administrative x $400/month → $ 4,800/year
  - 1 teacher x $400/month → $ 4,800/year
  - 1 nurse x $400/month → $ 4,800/year

Total casava processing unit expenses → 276 470 $/an

- **Tonnage of tuber cassava available → 2,250 t/year**
  - Area exploited = 225 hectares/year
  - Improved cassava productivity = 10 tons/hectare

- **Cost of cassava delivered to the factory → $105/t x 2,250 t/year ……………… → $ 236,250/year**

- **Cassava depreciation included in the carbonization depreciation item above**

- **Maintenance, consumables, water ……………………………………………… → $ 30,000/year**

- **Salaries …………………………………………………………………………………… → $ 10,220/year**
  - 7 employees x $4/day x 365 days = $10,220/year

Total of all site expenses → 1 462 280 $/an

Charcoal Recipes → 1 125 000 $/an

- Production capacity (expected yield 25% on dry matter) → 4,500 t/year
- Selling price in Kinshasa ($300/t), less transport ($50/t) → $ 250/t

Casava « bread flour » Recipes → 540 000 $/an

- Capacité de production (rendement 30 %, 2250 t x 0,3) → 675 t/an
- Selling price « at the factory door » → 800 $/t

Total of all site revenues → 1 665 000 $/an

Overall result of the Plantation/Charcoal/Casava semi-industrial unit
OPERATING RESULT (5 Ovens, 2500 ha) = + 202 720 $/an

- **Compte de résultat ②(French): 3500 ha, 7 fours, 6300 t/an makala, 945 t/an farine**

Économie d'échelle : Capacité de production ↗ …. Rentabilité ↗

The creation/operation of a 2500 ha estate and its living spaces based on the minimum technical configuration of 5 ovens generates a gross margin of $200,000/year. (Without Carbone Finance)
This gross margin is the minimum allowable to make the project attractive.

We will study the profitability for an increase in scale consistent with the context of land availability: Domain of 3500 ha / 7 ovens.

POUR UNE UNITÉ DE CARBONISATION DE 7 FOURS.

. La capacité nominale (maximale) de l'unité de carbonisation est de 21 fours/jour pendant 300 jours (à 4 tonnes de bois/four).
. Ou 20 fours/jour pendant 315 jours/an.

Soit une capacité maximale de carbonisation de 25 200 t de bois/an → 6300 t/an de charbon de bois

IL FAUT UN SITE DE 3500 ha = 3150 ha PLANTÉS + PARE-FEUX + VOIERIE + BATIMENTS + JARDINS + VERGERS AVEC UNE EXPLOITATION/REPLANTATION DE 315 ha/an

C'est une hypothèse conservatrice (de 25%) : 80 t/ha de bois sec carbonisable sur une rotation de 10 ans, Alors que les études du CIRAD à Mampu ont déterminé 107 t/an de bois sec carbonisable sur 10 ans.

Remarque : 1 four consomme 3600 t/an de bois pour une production de 900 t/an de charbon de bois
1 four a besoin de l'exploitation/replantation de 45 ha/an (3600 t de bois = 80 t/ha x 45 ha)
Soit une surface totale de plantation en croissance de 450 ha attribuée à 1 four

- **Investissements pour la configuration technique : 7 Fours**

Les Investissements de la plantation : 3150 ha plantés sur un domaine de 3500 ha

- De ce cas d'unité intégrée « Site de plantation agroforestière/Production Makala/Manioc », les engins tracteurs/remorques servent à l'ensemble des activités : transport des plants, plantation, entretien + transport du bois matière première vers la carbonisation.
  Par simplification, on affecte la totalité de leurs amortissements et de leurs consommables et entretiens à l'unité semi-industrielle de production.
  Donc ces utilisations d'engins n'apparaissent pas dans le poste plantation.
- La main d'œuvre de plantation et d'entretien des plantations est payée par le poste achat du manioc (105 $/t de tubercules) aux associations de villageois.
  Donc la charge salariale de la plantation/entretien n'apparaît pas dans le poste plantation.

Habituellement le coût de revient d'une plantation mature dans les conditions des Plateaux Bateke va de 2000 $/ha pour Mampu à 1500 $/ha pour IBI Village.

Ici, les opérations importantes de mise en terre des plants et d'entretien de la plantation (engins et main d'œuvre) sont supportées par les productions makala et manioc.
→ Donc l'investissement restant de plantation ne comprend plus que les pépinières et la préparation des parcelles (en grande partie mécanique défrichage, hersage, pare-feux …)

→ On prend un investissement restant de plantation de 1100 $/ha en référence aux études des chercheurs et aux spécificités du projet.

Investissement plantation à réaliser sur 5 à 8 ans : 3150 ha x 1100 $/ha = 3 465 000 $

Cet investissement est amorti dans le poste « Coût du bois matière première » à 13,75 $/t.

Les Investissements de la production semi-industrielle Makala/Manioc

- Usine de carbonisation (7 Fours) = 1 100 000 $ amortissable sur 15 ans → 73 333 $/an
- Atelier du manioc = 280 000 $ amortissable sur 10 ans → 28 000 $/an
- 7 tracteurs remorque = 350 000 $ amortissable sur 7 ans → 50 000 $/an
- 5 chariots élévateur (2x12 t + 3 x3,5 t) = 400 000 $ amortissable sur 7 ans → 57 140 $/an
- 2 broyeurs à branches (foyer biomasse) = 30 000 $ amortissable sur 7 ans → 4 300 $/an
- Terrassement du site de production = 300 000 $ amortissable sur 20 ans → 15 000$/an
  Surface de production 70 x 100 m
  Stabilisation, empierrement, Imperméabilisation, goudron, béton
- Voirie = 300 000 $ amortissable sur 20 ans → 15 000 $/an
- Bâtiments techniques = 550 000 $ amortissable sur 20 ans → 27 500 $/an
  Bureaux, vestiaires/douches, ateliers, magasin,
  Stockage conditionnement charbon de bois, Bâtiments atelier manioc
- Bâtiments sociaux = 400 000 $ amortissable sur 20 ans → 20 000 $/an
  Maisons villageois, école, dispensaire, foyer rencontre/loisir
- Eau = 250 000 $ amortissable sur 20 ans → 12 500 $/an
- Electricité (Groupe électro+réseau) = 100 000 $ amortissable sur 20 ans → 5 000 $/an
- Transports, douanes = 200 000 $ amortissable sur 15 ans → 13 330 $/an
- Engineering = 400 000 $ amortissable sur 12 ans → 33 333 $/an
- Divers, imprévus = 200 000 $ amortissable sur 12 ans → 16 667 $/an

Total investissements de l'unité de production + aménagements sociaux = 4 860 000 $

Total amortissements 371 100 $/an

Investissement global (Unité de production 7 Fours + Plantation + lieux de vie) = 8 325 000 $

Compte de résultat prévisionnel global de l'ensemble (7 Fours): « Plantation agroforestière + Productions Modernisées Makala/Manioc »

Total des charges de l'unité de carbonisation, de la plantation et de l'ensemble du lieu de vie. → ***1 553 040 $/an***

- **Tonnage de bois disponible et cycles de carbonisation → 25 200 t/an, 4 t/four, 20 fours/jour, 315 jours**
  - Surface exploitée = 315 hectares/an
  - Productivité de la plantation = 80 tonnes/hectare

- **Coût du bois matière première rendu usine → 29,5 $/t x 25 200 t/an → 743 400 $/an**
  - Coûts de pépinière, préparation plantation = 1100 $/ha, 80 t/ha → 13,75 $/t
  - Coût de bûcheronnage, débardage, chargement = 900 $/ha → 11,25 $/t
  - Transport sur site de carbonisation (3 $/km x 6 km pour 4 t/enceinte) → 4,5 $/t
    (6 km = une navette moyenne de 1 aller et retour de 3 + 3 km pour 4 t de bois)

- **Amortissements ……………………………………………………………… → 371 100 $/an**

- **Entretien, consommables techniques, eau, sacs conditionnement → <u>160 000 $/an</u>**

- **Gasoil ……………………………………………………………………………………. → <u>202 000 $/an</u>**
  (Approche moyenne : 7 engins x 5 l/h x 10,5 h/j x 315 j x 1,2 $/l = 139 000 $/an)
  (Groupe électrogène : 6 l/h x 24 h/j x 365 j x 1,2 $/l = 63 000 $/an)

- **Salaires ……………………………………………………………………………. → <u>77 040 $/an</u>**
  - 21 carbonisateurs caristes x 4 $/jour x 30 jours/mois x 12 mois → 30 240 $/an
  - 2 techniciens x 450 $/mois → 10 800 $/an
  - 1 + 1 + 1 responsables de site x 600 $/mois → 21 600 $/an
  - 1 administratif x 400 $/mois → 4 800 $/an
  - 1 instituteur x 400 $/mois → 4 800 $/an
  - 1 infirmier x 400 $/mois → 4 800 $/an

<u>Total des charges de l'unité de transformation de manioc → 390 350 $/an</u>

- **Tonnage de manioc tubercule disponible → 3 150 t/an**
  - Surface exploitée = 315 hectares/an
  - Productivité manioc améliorée = 10 tonnes/hectare

- **Coût du manioc rendu usine → 105 $/t x 3 150 t/an …………….. → <u>330 750 $/an</u>**

- **Amortissements manioc inclus dans le poste ci-dessus amortissements carbonisation**

- **Entretien, consommables, eau ………………………………………… → <u>45 000 $/an</u>**

- **Salaires ……………………………………………………………………… → <u>14 600 $/an</u>**
  - 10 employé(es) x 4 $/jour x 365 jours = 14 600 $/an

<u>Total de l'ensemble des charges du site → 1 933 390 $/an</u>

<u>Recettes charbon de bois → 1 575 000 $/an</u>

- Capacité de production (rendement escompté 25 % sur matière sèche) → 6 300 t/an
- Prix de vente à Kinshasa (300 $/t), diminué du transport (50 $/t) → 250 $/t

<u>Recettes manioc « farine panifiable » → 756 000 $/an</u>

- Capacité de production (rendement 30 %, 3150 t x 0,3) → 945 t/an
- Prix de vente « à la porte de l'usine » → 800 $/t

<u>Total de l'ensemble des recettes du site → 2 331 000 $/an</u>

Résultat global de l'unité semi-industrielle Plantation/charbon/manioc
RÉSULTAT D'EXPLOITATION (7 Fours, 3500 ha) = + 397 610 $/an

- **Income statement ③ : 5000 ha, 10 Ovens, 9000 t/year makala, 1350 t/year flour**

Économy of scale : Production capacity ↗↗ …. Profitability ↗↗

The optimal size of Community Agroforestry Plantation units associated with their semi-industrial Makala/Cassava production unit is 5,000 ha.
In this case, the semi-industrial site remains of a reasonable size and the area of 5,000 ha (7 x 7 km). This surface is readily available on Bateke Plateaux.

FOR A 10 FURNACES CARBONISATION UNIT.

. The nominal (maximum) capacity of the carbonization unit is 30 kilns/day for 300 days (at 4 tons of wood/kiln).
. Or 28 ovens/day for 322 days/year.

i.e. a maximum carbonization capacity of 36,000 t of wood/year → 9,000 t/year of charcoal

IT NEEDS A SITE OF 5000 ha = 4500 ha PLANTED + FIREBREAKS + ROADS + BUILDINGS + GARDENS + ORCHARDS WITH AN EXPLOITATION/REPLANTATION OF 450 ha

This is a conservative assumption (25%): 80 t/ha of carbonizable dry wood over a rotation of 10 years, Whereas CIRAD studies in Mampu determined 107 t/year of carbonizable dry wood over 10 years.

Note : 1 kiln consumes 3600 t/year of wood for a production of 900 t/year of charcoal
1 kiln needs the exploitation/replanting of 45 ha/year (3600 t of wood = 80 t/ha x 45 ha)
That is a total area of growing plantation of 450 ha allocated to 1 kiln

- **Investments for technical configuration : 10 Ovens**

Plantation Investments : 4500 ha planted on a 5000 ha estate

- In this case of an integrated "Agroforestry planting site/Makala/Cassava production" unit, tractors/trailers are used for all activities: transport of seedlings, planting, maintenance + transport of raw material wood to carbonization.
  For simplicity, all of their depreciation, consumables and maintenance are allocated to the semi-industrial makala/cassava production unit.
  So these uses of machinery do not appear in the planting item.

- Labor for planting and maintaining plantations is paid by the cassava purchase item ($105/t of tubers) to village associations.
  Therefore, the planting/maintenance payroll does not appear in the planting item.

Usually the cost price of a mature plantation under the conditions of the Bateke Plateaux ranges from $2,000/ha for Mampu to $1,500/ha for IBI Village.

Here, the important operations of planting seedlings and maintaining the plantation (machinery and labour) are supported by makala and cassava production.
→ So the remaining plantation investment only includes nurseries and plot preparation (largely mechanical clearing, harrowing, firebreaks, etc.)

→ We take a remaining planting investment of $1,100/ha in reference to the researchers' studies and the specificities of the project.

Plantation investment to be made over 5 to 8 years: 4 500 ha x $ 1,100/ha = $ 4 950 000

This investment is depreciated in the "Cost of wood raw material" item at $13.75/t.

Investments in semi-industrial Makala/Casava production

- Carbonization plant (10 furnaces) = $1,250,000 depreciable over 15 years → $ 83,333/year
- Cassava workshop = $320,000 depreciable over 10 years → $ 32,000/year
- 8 trailer tractors = $400,000 depreciable over 7 years → $ 57,143/year
- 6 forklifts (3x12 t + 3 x3.5 t) = $500,000 depreciable over 7 years → $ 71,430/year
- 3 wood chippers (biomass fireplace) = $45,000 depreciable over 7 years → $ 6,430/year
- Excavation of the production site = $350,000 depreciable over 20 years → $ 17,500/year
  Production area 70 x 100 m
  Stabilization, stonework, waterproofing, tar, concrete
- Roads = $350,000 depreciable over 20 years → $ 17,500/year
- Technical buildings = $600,000 depreciable over 20 years → $ 30,000/year
  Offices, changing rooms/showers, workshops, store,
  Charcoal packaging storage, Cassava workshop buildings
- Social buildings = $450,000 depreciable over 20 years → $ 22,500/year
  Village houses, school, dispensary, meeting/leisure center
- Water = $280,000 depreciable over 20 years → $ 14,000/year
- Electricity (electro unit + network) = $150,000 depreciable over 20 years → $ 7,500/year
- Transportation, customs = $230,000 depreciable over 15 years → $ 15,333/year
- Engineering = $420,000 depreciable over 12 years → $ 35,000/year
- Miscellaneous, contingencies = $230,000 depreciable over 12 years → $ 19,167/year

Total production unit investments + social amenities = 5 575 000 $

Total amortization 428 836 $/an

Overall investment : Production unit 10 Fours + Plantation + living spaces = 10 525 000 $

Overall provisional income statement of the whole (10 ovens):
« Agroforestry plantation + Modernized Makala/Casava productions »

Total carbonization unit expenses, → $ 2,119 586/year
of the plantation and the whole place of life.

- **Tonnage of wood available and carbonization cycles → 36,000 t/year, 4 t/kiln, 30 kilns/day, 300 days**
  - Area exploited = 450 hectares/year
  - Productivity of the plantation = 80 tons/hectare

- **Cost of raw material wood delivered to the factory → $29.50/t x 36,000 t/year → $ 1 062,000/year**
  - Nursery costs, planting preparation = $1100/ha, 80 t/ha → $13.75/t
  - Cost of logging, skidding, loading = $900/ha → $11.25/t
  - Transport to the carbonization site ($3/km x 6 km for 4 t/enclosure) → $4.5/t
  (6 km = an average shuttle of 1 return trip of 3 + 3 km for 4 t of wood) x 12 shuttles/day

- **Amortizations ………………………………………………………… → $ 428 836/year**

- **Maintenance, technical consumables, water, packaging bags → $ 228 600/year**

- **Diesel ……………………………………………………………………………………. → $ 298 110/year**
  (Average approach: 9 gears x 5,5 l/h x 12 hrs/d x 315 d x $1.2/l = $ 224 530/year)
  (Genset: 7 l/h x 24 h/d x 365 d x $1.2/l = $73,580/year)

- **Wages ………………………………………………………………………… → $ 104 040/year**
  - 30 forklift carbonizers x $4/day x 30 days/month x 12 months → $ 30 240/year
  - 3 technicians x $450/month → $ 16 200/year
  - 1 + 1 +1 +1 site managers x $600/month → $ 28 800/year
  - 1 +1 administrative x $400/month → $ 9 600/year
  - 2 teachers x $400/month → $ 9 600/year
  - 2 nurse x $400/month → $ 9 600/year

Total casava processing unit expenses → 549 400 $/an

- **Tonnage of tuber cassava available → 4 500 t/year**
  - Area exploited = 450 hectares/year
  - Improved cassava productivity = 10 tons/hectare

- **Cost of cassava delivered to the factory → $105/t x 4 500 t/year ……………. → $ 472 500/year**

- **Cassava depreciation included in the carbonization depreciation item above**

- **Maintenance, consumables, water ……………………………………………. → $ 55,000/year**

- **Salaries ………………………………………………………………………… → $ 21 900/year**
  - 15 employees x $4/day x 365 days = $21 900/year

Total of all site expenses → 2 669 256 $/an

Charcoal Recipes → 2 250 000 $/an

- Production capacity (expected yield 25% on dry matter) → 9 000 t/year
- Selling price in Kinshasa ($300/t), less transport ($50/t) → $ 250/t

Casava « bread flour » Recipes → 1 080 000 $/an

- Capacité de production (rendement 30 %, 2250 t x 0,3) → 1 350 t/an
- Prix de vente « à la porte de l'usine » → 800 $/t

Total of all site revenues → 3 330 000 $/an

Overall result of the Plantation/Charcoal/Casava semi-industrial unit
OPERATING RESULT (10 Ovens, 5000 ha) = + 660 744 $/an

Productions capacities / Investments / Profitability / « Réductions CO_2 »

Superficie du domaine	① **2500 ha**	② **3500 ha**	③ **5000 ha**
Superficie plantée	2250 ha	3150 ha	4500 ha
Nombre de ovens	5	7	10
Production makala	4500 t/an	6300 t/an	9000 t/an
Production casava wheat	657 t/an	945 t/an	1350 t/an
Invest. Plantation	2 475 000 $	3 465 000 $	4 950 000 $
Invest. Site prod + social	4 580 000 $	4 860 000 $	5 575 000 $
Investment total	7 055 000 $	8 325 000 $	10 525 000 $
Operating result	**202 720 $/an**	**397 610 $/an**	**660 744 $/an**
Cumulative C02 Réductions in 15 years of operation (Duration of technical depreciation)			
Forest Carbon sink Permanent	250 000 t de CO_2	350 000 t de CO_2	500 000 de CO_2
Carbone sink biochar permanent for 15 years	17 325 t de CO_2	24 255 t de CO_2	34 650 de CO_2
Réduction d'émission C02 Makala déforestation substitué par Makala durable	55 000 tCO_2/year 825 000 tCO_2/15years	77 000 tCO_2/year 1 155 000 tCO_2/15years	110 000 tCO_2/year 1 650 000 tCO_2/15years
Cumulative CO_2 Réduction In 15 years of operation	**1 092 325 t de C02**	**1 529 255 t de C02**	**2 185 650 t de C02**

The configuration of 5,000 ha/10 kilns generates an excellent gross margin, which is attractive to the private sector.

- This level of gross margin makes it possible to remunerate the capital contribution and the cost of private land,
- To support upward revisions of the costing of the items of this forecast account,
- Release funds for the extension of forest cover.

Thanks to the **profitability** of this "Sustainable Bioenergy" project, we can envisage the development on a large scale of this "Green Economy" sector to:
- ① Substitute the huge quantities of unsustainable charcoal consumed by urban households with low purchasing power and fight effectively against this driver of deforestation,
- ② Secure the sanitary quality of cassava processing (Serious public health issue: Food poisoning is currently recurrent through the consumption of poorly dried cassava by artisanal processes) and

Substitute part of the large volumes of imported wheat with national agricultural production.

Conclusion :

This energy optimization technology, based on sustainable wood energy deposits, produces sustainable charcoal and optimizes (saves) the use of raw material wood.
It replaces current informal production with low energy yield resulting from the degradation of forest and agroforestry cover.

The processing of cassava is secure and makes it possible to move towards the production of bread-making cassava flour with better added value. Improving this value chain, managed by women, doubles their income.
This technology bears the cost of renewing the agroforestry plantation used and makes it possible to pay decent and regular wages.
It generates a profit margin that makes it possible to self-finance the extension of agroforestry areas to degraded savannah peri-urban areas.

Agricultural and forestry jobs are maintained. In the cassava carbonization and processing units, stable, qualified and well-paid jobs are created.

The purification of fumes complies with European standards for the quality of atmospheric emissions (ELV, Emission Limit Values of the IED directive - 2010/75/EU).
The negative impacts of artisanal productions, on the environment and health conditions at work and for the neighborhood, are now eliminated.

The permanent availability of heat, regardless of rainy weather conditions (1900 mm in 2021), avoids significant production losses from small-scale cassava processing and improves carbonization productivity.

Socio-economic, climatic and environmental interests are converging.

The implementation of a unit of this technical model could serve as a demonstrator, with a view to its duplication, for the substitution of the enormous quantities of unsustainable charcoal consumed by urban households.
Kinshasa consumes 2.14 million t/year of charcoal in 2021 – Ref. CIRAD – based on the degradation of forest and agroforestry environments, i.e. the colossal equivalent of the energy power of three 900 MW nuclear reactors!!, based at every moment on the disappearance of trees and their biotope by multiplying the areas abandoned by rural exodus.

The strategic objective of promoting a greener charcoal value chain for Central Africa and more generally for SSA has been widely developed by FAO since 2017 in the study “The Charcoal Transition”.
Conclusion FAO: "In the foreseeable absence, in the next thirty years, of realistic, affordable and renewable alternatives, it seems essential to embark on the path of greening the charcoal value chain. to mitigate the effects of climate change while maintaining household access to a renewable energy source”.
The FAO recommends the "High yielding, low emission charcoal factories" track based on socially integrated renewable biomass resources.

The installation of agroforestry plantations associated with this new technical concept of energy optimization as well as its socio-environmental benefits, are part of the process of creating the ecological corridor of the Batéké Plateaux (CEBAT).
Sustainable agroforestry plantations installed around the reserves constitute a protective buffer zone, for example for the Bombo Lumene reserve (ICCN) near Kinshasa. Initial financial support for the launch of a demonstrator of the “Afforestation/Technical Modernization of Production” project is part of the strengthening of this function.

Economic, social, environnemental, climate and gender interests converge.

The integrated semi-industrialization of sustainable “cassava carbonization/processing” sectors,
- Based on “community agroforestry plantations of sustainable wood energy”,
- Which valorizes the thermal energy produced by the depollution/incineration of fumes in a cassava processing workshop and in improving the productivity of makala is :

→ A sustainable, financially self-balancing process that generates additional revenue for the benefit of local populations and the extension of community agroforestry cover.

→ This model for implementing "energy optimization" in the field of sustainable charcoal is "now profitable" by integrating all the initial and operating costs of the plantation.

→ It allows the large-scale development of a "Biomass Energy Private Sector" in the "Green and solidarity economy", based on commercial revenues (and not on subsidies) which is intended to replace the huge current productions not sustainable domestic fuelwood based on the degradation of forest cover and ecosystems. It secures the sanitary quality of cassava.

→ Only the initial funding necessary to boost this innovative sector must be supported by the institutions to create the first demonstration sites on existing agroforestry sites. (IBI Village, Mampu, Ntsio and some private).

Carbon finance can supplement these numerous socio-environmental benefits by promoting CO2 emission reductions over 15 years of :
- **1 million tonnes CO2 for a 2,500 ha site,**
- **2 million tonnes CO2 for a 5,000 ha site.**

The social and environmental performance of the project makes it possible to consider a good recovery of the ton of CO2.

COMMUNITY AGROFORESTRY
MAKALA/CASAVA/++ (07/2022)

CO2 EMISSION RÉDUCTIONS IN THE PROJECT :

« ENERGY OPTIMIZATION OF INTÉGRATED CHARCOAL AND CASAVA PRODUCTIONS »

1) CO2 Emission Réduction : The « sustainable charcoal » is substituted for unsustainable charcoal from deforestation

For the production of charcoal from a source of renewable wood: Agroforestry,
The IPPC/IPCC and the UNFCC in the methodologies of the "CDM, Clean Development Mechanism" note that the wood consumption of African informal artisanal production of unsustainable charcoal is 8.3 kg of wood/1 kg of charcoal.
→ So for a production 1 of 4,500 t/year of charcoal, the saving of unsustainable wood from deforestation is 8.3 x 4,500 = 37,350 t/year, i.e. (x 0.49) 18,300 t/year of Carbon, i.e. an equivalent CO2 emission reduction of 16,600 x 44/12 = 67,100 t CO2/year.
This reduces project leaks (eg diesel fuel consumed).

Or for production 1: 4500 t/year of sustainable charcoal = 55,000 t/year of CO2 reduction by avoiding the deforestation of traditional non-sustainable charcoal.

2) The permanent forestal carbon sink for agroforestry plantation.

Example of Production 1: After 10 years of growth for an area of 2500 ha, 2250 ha planted.
According to the 2017 CIRAD study "Acacia auriculiformis production, in the Mampu agroforestry system, Batéké plateau (DRC)"
The production of dry matter after 10 years of growth is:

- total aerial: 145 t/ha.10 years
- underground: 26.1 t/ha.10 years (145 x 0.18 extrapolation)
- total biomass: 171.1 t/ha.10 years
- i.e. an average productivity of 17 t/ha.year

So the average CO2 storage is 30 tCO2/ha.year (17 x 0.49 x 44/12)
A 225 ha plot accumulates 6,750 tCO2/year

Total accumulation after 9 years of growth: (we exploit at 10 years)
1 plot of 225 ha 9 years old
1 plot of 225 ha 8 years old
1 plot of 225 ha 7 years old
………………
1 plot of 225 ha 1 year old

Therefore, the biomass accumulation of the 9 plots of 225 ha planted each year is:
6750 x (1 + 2 + 3 …. + 9) = (6750 x n (n+1)/2) = 6750 x 45 = 303,750 t of CO2 minus the carbon present in the original grassy savannah and minus consumption of diesel (tractors).

For production 1 2500 ha: A permanent forest carbon sink of approximately 250,000 t of CO2.

Diagram of a planting sequence and age of planting on each plot (here Ex. Rotation 10 years)

Year n	n° Plots (225 ha)										
	1	2	3	4	5	6	7	8	9	10	11
1	création of afforestation										
1	1	0	0	0	0	0	0	0	0	0	0
2	2	1	0	0	0	0	0	0	0	0	0
3	3	2	1	0	0	0	0	0	0	0	0
4	4	3	2	1	0	0	0	0	0	0	0
5	5	4	3	2	1	0	0	0	0	0	0
6	6	5	4	3	2	1	0	0	0	0	0
7	7	6	5	4	3	2	1	0	0	0	0
8	8	7	6	5	4	3	2	1	0	0	0
9	9	8	7	6	5	4	3	2	1	0	0
10	10	9	8	7	6	5	4	3	2	1	0
11	Start of carbonization/Harvest and afforestation operation										
11	0	10	9	8	7	6	5	4	3	2	1
12	1	0	10	9	8	7	6	5	4	3	2
13	2	1	0	10	9	8	7	6	5	4	3

3) The stable carbon sink of the burial in the superficial soil of the fertilizer BIOCHAR.

The production of 4,500 t/year of "marketable pieces of charcoal" produces around 7% of fines (flakes) which will be used as fertilizing biochar. (1t/ha)
That is 315 t/year of biochar used as fertilizer.
This biochar is amorphous in the soil, it remains in the form of non-oxidizable carbon in CO2.
So the avoidance of an emission of 1,155 t of CO2 (315 x 44/12).
This represents a cumulative carbon sink of 1,155 t of CO2 for each year of production.

For 15 years of production (depreciation period of the carbonization unit), this represents For production ①: 4500 t/year of Makala = A permanent biochar carbon sink of 17,325 t of CO2. (1,155 t/year x 15 years).

COMMUNITY AGROFORESTRY MAKALA/CASAVA/++ (07/2022)

STATUS OF WOMEN IN THE PROJECT :

« ENERGY OPTIMIZATION OF INTÉGRATED CHARCOAL AND CASAVA PRODUCTIONS »

<u>Family food crop activities.</u>
Independently or with men, women cultivate gardens and orchards to feed the community.

→ <u>Income-generating activities for women: Cassava - The benefits of the project.</u>

The cooperatives of village women with the men carry out the operations of plantation of wood energy.
The women's remuneration is based on the intercropping of cassava which they do for 2 years from the start of the plantation. (Rows of cassava between the rows of acacias)
The cassava harvest belongs to them.
Unfortunately, after the harvest of the tubers, the artisanal means of transformation are very uncertain for the drying operation (latent humidity and violent unpredictable storms).
Indeed cassava must imperatively be dried within 12 hours otherwise it is fermented/lost.
With artisanal processing, village women lose half of the potential income from their crops.
(Incomplete natural drying → Food poisoning,
and often impossible natural drying → Lost product, loss of recipe).

→ The use of the heat produced by the depollution of fumes from the carbonization unit secures the cassava drying operation: Avoidance of all tuber production losses. So the remuneration of the villagers will increase thanks to the new efficient drying.

→ The use of the heat produced by the depollution of fumes from the carbonization unit makes it possible to carry out drying which guarantees a precise degree of residual humidity, therefore to produce cossettes of good sanitary quality and "Cassava Flour bread-making”.
This flour has a higher selling price than the chips usually sold.
Thanks to this new production with better added value: the income of women increases significantly.

The modernization of carbonization and its production of free heat in the service of processing cassava into bread flour will make cassava cultivation twice as profitable for the benefit of women compared to current artisanal processes. And that without imported fossil energy.

It should be noted that this <u>"locally produced cassava flour" replaces "imported wheat flour"</u>.

<u>→ The new semi-industrial carbonization unit produces BIOCHAR.</u>

It is a soil fertilizer.
Buried in the surface layer and by its properties of capturing and retaining molecules, it avoids the leaching, by heavy rains, of the nutrients and water necessary for the development of plants.

Many agronomic studies demonstrate the effectiveness of biochar on plant growth and the possibility of significantly reducing the use of agricultural amendments.

Improving the productivity of women's food gardens and orchards will benefit from this new production of biochar fertilizer.
Consult the "International Biochar Initiative" website. "IBI" (it is a namesake of IBI Village).

<u>→ Installation of water points near the living areas of the project.</u>
<u>Electrification of the project perimeter.</u>

These 2 service supplies (water and electricity) significantly improve women's living conditions by reducing the daily costs they bear.

<u>→ The sanitary quality of cassava food consumption.</u>

The technical control of the drying parameters makes it possible to obtain a guarantee of the sanitary quality of the marketed product and to avoid frequent/recurring food poisoning from artisanal production which currently represents a food security issue in the DRC.

Women, responsible for family food, benefit directly from the availability of this cassava of high sanitary quality, the current recurrent food poisonings disappear.