IEA Bioenergy Task 32:
Workshop on the Opportunities for Bioenergy in South Africa

Rural Energy: Improved Charcoal Production and Woodstoves

Mike Temmerman
Johannesburg,
04/11/2014

Walloon Agricultural Research Center – CRA-W
U13 – Biomass, Bioproducts & Energy
www.cra.wallonie.be – M. Temmerman – temmerman@cra.wallonie.be

cra-w
Centre wallon de Recherches agronomiques
Wallonie

Introduction

- *In many African countries, the domestic energy needed for cooking purposes and sometimes for heating find its origin in the forest*
  - *Wood energy*
  - *Charcoal*
- *Wood needed to produce these fuels, in the best cases comes from*
  - *Energy crops*
    - *Eucalyptus or Acacia plantations around some African capitals*
    - *Planted in the eighties, but still producing wood for energy*
  - *Sawmill residues*
  - *Well managed forests*

- *The wood is still often collected without active control and this lead to an overexploitation of forests*
  - *The driest the forest is, the more evident the overexploitation is*

arch Center – CRA-W
oducts & Energy
n – temmerman@cra.wallonie.be

Introduction

- *Wood fuel is often opposed to Charcoal*
  - *Due to the low yields of traditional process production, charcoal has a bad reputation, but in practice, both fuels are complementary*
  - *Wood fuel is used when forest are close, as it is the case*
    - *in rural areas*
      - *In this case wood is often collected, but not commercialized, which ends in an uncontrolled pressure on forests*
    - *In secondary cities located in forest areas*
      - *In this case wood fuel supply area is continuously increasing*
      - *Wood may be transported up to 60 km*

Walloon Agricultural Research Center – CRA-W
U13 – Biomass, Bioproducts & Energy
www.cra.wallonie.be – M. Temmerman – temmerman@cra.wallonie.be

Introduction

- *Charcoal is first a fuel intended to be transported*
  - *It is always commercialized*
    - *Charcoal makers have to be paid for their work*
    - *Makes a control of the market possible*
  - *In Senegal, Cameroun, Burkina Faso, charcoal may be transported on distances up to 1000 km*

Walloon Agricultural Research Center – CRA-W
U13 – Biomass, Bioproducts & Energy
www.cra.wallonie.be – M. Temmerman – temmerman@cra.wallonie.be

Introduction

- *Woodfuel & Charcoal have common characteristics:*
  - *High pressure on forest*
  - *GHG emissions in case of unmanaged forest or charcoal production*
  - *Uses characterized by*
    - *Low combustion yields*
    - *Emissions related to low combustion yields*

- *Possible solutions are:*

  - *The use of substitution fuels*
    - *Made from agricultural residues*
    - *Many projects have been set up, but few are "self supporting", mainly due to high production costs compared to traditional fuels*
    - *This aspect has high potentialities, but will not be describe further here*

  - *Improvement of the environmental impact of charcoal production*
    - *The opportunity of using sawmills residues*
    - *Improvement of charcoal production yields*

  - *Improvement of conversion yields*
    - *Improved stoves*

Walloon Agricultural Research Center – CRA-W
U13 – Biomass, Bioproducts & Energy
www.cra.wallonie.be – M. Temmerman – temmerman@cra.wallonie.be

Introduction

- *Woodfuel & Charcoal have common characteristics:*
  - *High pressure on forest*
  - *GHG emissions in case of unmanaged forest or charcoal production*
  - *Uses characterized by*
    - *Low combustion yields*
    - *Emissions related to low combustion yields*

- *Possible solutions are:*

  - *The use of substitution fuels*
    - *Made from agricultural residues*
    - *Many projects have been set up, but few are "self supporting", mainly due to high production costs compared to traditional fuels*
    - *This aspect has high potentialities, but will not be describe further here*

  - ***Improvement of the environmental impact of charcoal production***
    - ***The opportunity of using sawmills residues***
    - ***Improvement of charcoal production yields***

  - ***Improvement of conversion yields***
    - ***Improved stoves***

Walloon Agricultural Research Center – CRA-W
U13 – Biomass, Bioproducts & Energy
www.cra.wallonie.be – M. Temmerman – temmerman@cra.wallonie.be

- ***Improvement of the environmental impact of charcoal production***
  - ***The opportunity of using sawmills residues***
  - *Improvement of charcoal production yields*

- *Improvement of conversion yields*
  - *Improved stoves*

Walloon Agricultural Research Center – CRA-W
U13 – Biomass, Bioproducts & Energy
www.cra.wallonie.be – M. Temmerman – temmerman@cra.wallonie.be

Improvement of the environmental impact of charcoal production

- Sawmills have production yields of 50% in the best case
- In equatorial sawmills, residues are in most cases unused
  - Few amounts are used to produced charcoal, on traditional way
  - There are only few examples of use of these residues for cogeneration even if producers are aware of this possibility and generally outside the electricity grid
  - Most of the residues are burn in open air

Walloon Agricultural Research Center – CRA-W
U13 – Biomass, Bioproducts & Energy
www.cra.wallonie.be – M. Temmerman – temmerman@cra.wallonie.be

Wallonie

Improvement of the environmental impact of charcoal production

- Use of unused resources: particular case of equatorial forest sawmills
  - Sawmills have production yields of 50% in the best case
  - Residues are in most cases unused
    - Few amounts are used to produced charcoal, on traditional way
    - There are only few examples of use of these residues for cogeneration even if producers are aware of this possibility and generally outside the electricity grid
    - Most of the residues are burn in open air

- The production of charcoal from these residues has different impacts
  - The charcoal produced will be used instead of charcoal which would be produced anyway, sometimes in less productive forests
  - Avoids open air combustion of sawmills residues
  - Allows a centralized charcoal production and the use of improved charcoal production techniques

Centre wallon de Recherches agronomiques

Walloon Agricultural Research Center – CRA-W
U13 – Biomass, Bioproducts & Energy
www.cra.wallonie.be – M. Temmerman – temmerman@cra.wallonie.be

Wallonie

- ***Improvement of the environmental impact of charcoal production***
  - *The opportunity of using sawmills residues*
  - ***Improvement of charcoal production yields***

- *Improvement of conversion yields*
  - *Improved stoves*

Walloon Agricultural Research Center – CRA-W
U13 – Biomass, Bioproducts & Energy
www.cra.wallonie.be – M. Temmerman – temmerman@cra.wallonie.be

Improvement of charcoal production yields

- The charcoal production yield: definitions
  - The mass yield

$$MY_{ab} = \frac{M_{ca}}{M_{wa}} 100$$

    - Where
      - MY_{ab} is the mass yield
      - M_{ca} is the mass of anhydrous charcoal
      - M_{wa} is the mass of anhydrous wood

  - Energy yield (based on higher calorific value)

$$EY' = \frac{M_{ca}}{M_{wa}} \frac{HCV_{ca}}{HCV_{wa}} 100$$

    - Where
      - EY' is the energy yield
      - M_{ca} is the mass of anhydrous charcoal
      - M_{wa} is the mass of anhydrous wood
      - HCV_{ca} is the higher calorific value of Charcoal
      - HCV_{wa} is the higher calorific value of wood

- As wood only contains 50% Carbon, the mass yield cannot go over this theoretical limit, in practice mass yields are lower
- This yield is often used in practice due to the easiness to determine it
- The low value of mass yields may explain the bad image of carbonization processes
- Charcoal calorific value is higher then wood
- The energy yield is increased in consequence

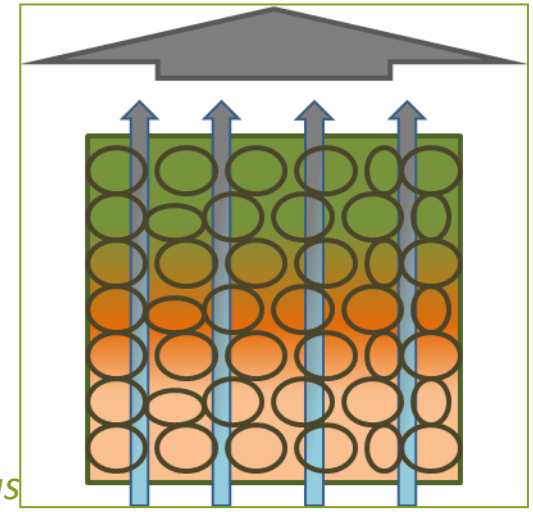
Wallonie

Improvement of charcoal production yields

- Charcoal production technologies: 2 main groups

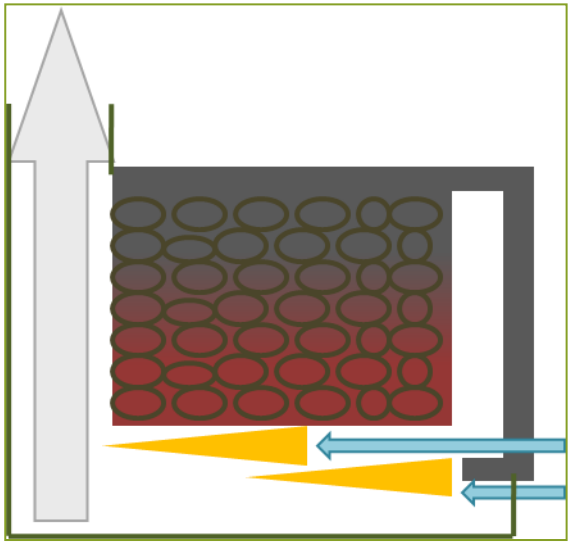
  - Partly combusted load processes
    - Traditional mound kilns
    - Charcoal pits
    - Brick kilns
    - Metal kilns

    - The necessary heat for carbonization comes from the combustion of a part of the wood of the load, with no recovery, nor combustion of the pyrolysis gas



  - Retort kilns
    - Metal retort kilns
    - Industrial continuous processes
    - Recent brick retort kilns

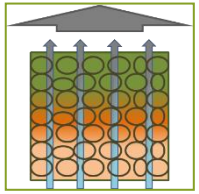
    - Pyrolysis gas are combusted and the generated flue gas are used heat the wood load

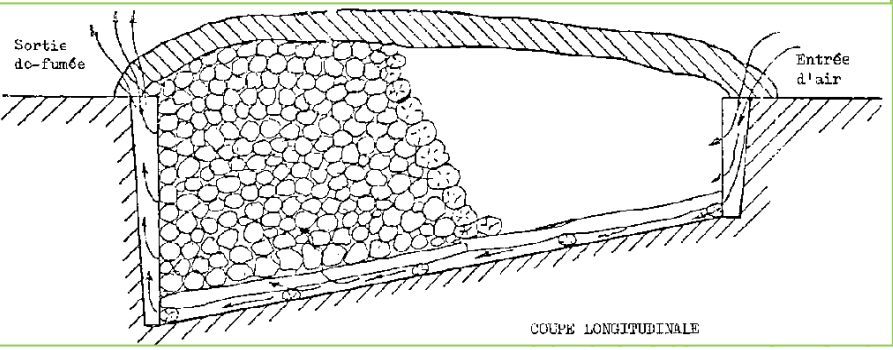


Walloon Agricultural Research Center – CRA-W
U13 – Biomass, Bioproducts & Energy
www.cra.wallonie.be – M. Temmerman – temmerman@cra.wallonie.be

Improvement of charcoal production yields

- *Partly combusted load processes*
- *Traditional mound kilns & Charcoal pits*





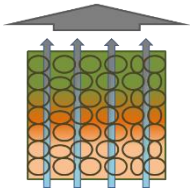
rch Center – CRA-W
ducts & Energy
– temmerman@cra.wallonie.be

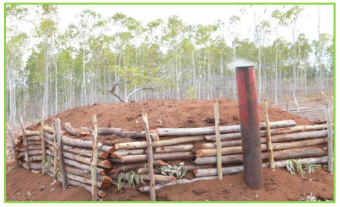
Centre wallon de Recherches agronomiques

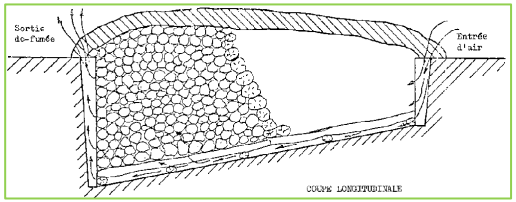
Wallonie

Improvement of charcoal production yields

- Partly combusted load processes
- Traditional mound kilns





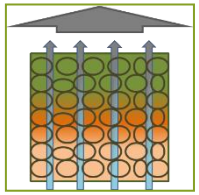


- Advantages
  - Mobile
  - Made of local materials
  - No or very low investment
  - Adjustable capacity
- Weak points
  - Highly depending on the skills of charcoal makers
  - High and permanent workload
  - Random production
    - High risk of complete combustion of the load
  - Varying quality of the produced charcoal
  - High pollution due to incomplete combustion
    - CH_4 emissions (2,5% of emitted gas is considered here)
  - Low mass yield
    - From 12 to 25%
    - Typically 17%

Walloon Agricultural Research Center – CRA-W
U13 – Biomass, Bioproducts & Energy
www.cra.wallonie.be – M. Temmerman – temmerman@cra.wallonie.be

Improvement of charcoal production yields

- *Partly combusted load processes*
- *Brick & metal kilns*



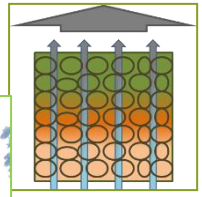
ricultural Research Center – CRA-W
Biomass, Bioproducts & Energy
M. Temmerman – temmerman@cra.wallonie.be

Centre wallon de Recherches agronomiques

Wallonie

Improvement of charcoal production yields

- Partly combusted load processes
- Bricks & metal kilns

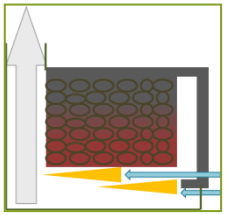


- Advantages
  - Short & regular carbonization process
  - Easy process to conduct
  - Homogenized production
    - Charcoal quality
    - Lower risk of complete combustion of the load
- Weak points
  - Need of skilled workers to produce the kilns
  - Fixed capacity
  - Transport of raw material needed
  - High pollution due to uncompleted combustion
    - CH_4 emissions (2,5% of emitted gas is considered here)
  - Low mass yield
    - From 12 to 30 %
    - Typically 22 %

Agricultural Research Center – CRA-W
3 – Biomass, Bioproducts & Energy
e – M. Temmerman – temmerman@cra.wallonie.be

Improvement of charcoal production yields

- *Retort Kilns*
- *Industrial processes*



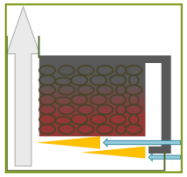
Centre wallon de Recherches agronomiques

Walloon Agricultural Research Center – CRA-W
U13 – Biomass, Bioproducts & Energy
www.cra.wallonie.be – M. Temmerman – temmerman@cra.wallonie.be

Wallonie

Improvement of charcoal production yields

- Retort Kilns
- Industrial processes



- Advantages
  - Continuous process
  - Homogenized production
    - High charcoal quality
  - Pyrolysis gas combustion (no CH_4 emissions)
  - High production yields
    - 35% and above
- Weak points
  - High investment needed
  - There are many methods for implementing the retort principles
  - Most of them have been developed by the charcoal producers themselves and few are commercially available
  - Many of these producers are no longer in use which has for consequence a lost of knowledge
  - Some names remain
    - Lambiotte
    - Martezo
    - Herreshoff

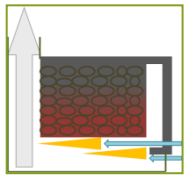
Centre wallon de Recherches agronomiques

Walloon Agricultural Research Center – CRA-W
U13 – Biomass, Bioproducts & Energy
www.cra.wallonie.be – M. Temmerman – temmerman@cra.wallonie.be

Wallonie

Improvement of charcoal production yields

- Retort Kilns



- Small scale processes

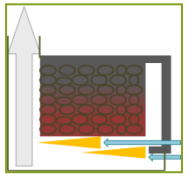
- The "Adam retort Kiln"
- was the first one to consider the possibility to adapt the retort principle on small scale , low investment carbonization process
- It is now well spread in countries producing charcoal
- The drawings and an user license may be purchased at the inventor of the concept
- The main advantage of this process is to allow to burn pyrolysis gas before releasing in the atmosphere
- An external combustion chamber allows to burn fuels not suitable for charcoal production

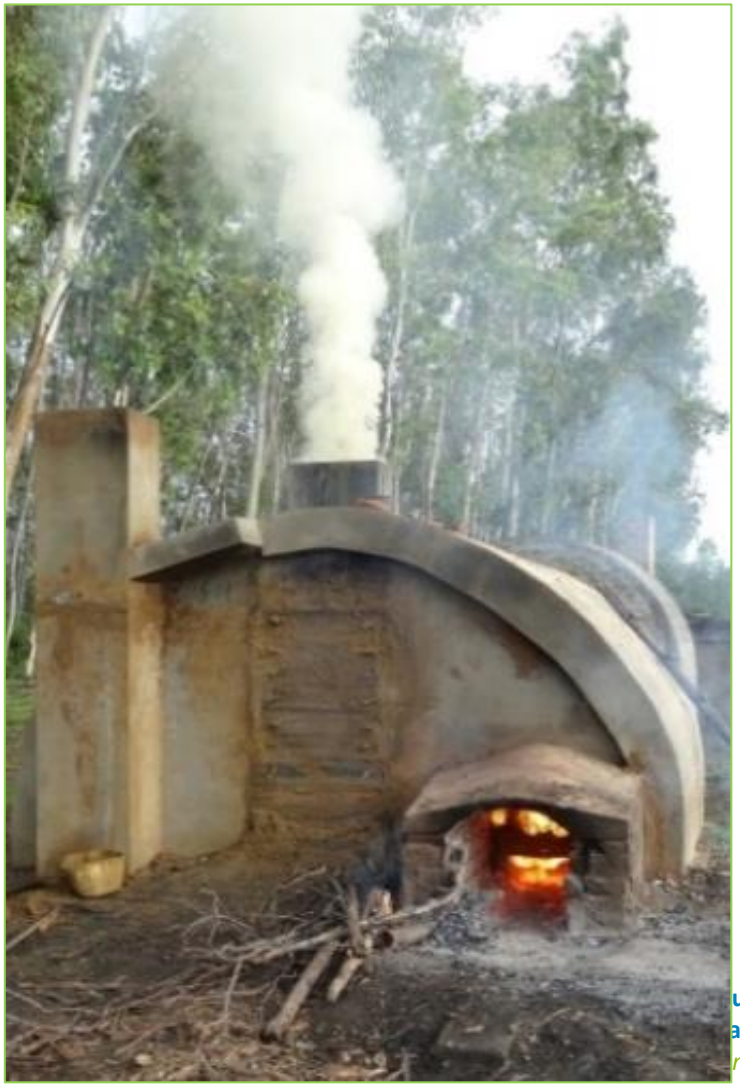
- However some weak point have been noticed at several users
  - Incomplete sealing of the walls making difficult to cool the load without losses due to combustion
  - Need of water to cool down the charcoal which leads to lower charcoal quality or needs additional drying
  - Pyrolysis gas are burned without heat recovery

Walloon Agricultural Research Center – CRA-W
U13 – Biomass, Bioproducts & Energy
www.cra.wallonie.be – M. Temmerman – temmerman@cra.wallonie.be

Improvement of charcoal production yields

- *Retort Kilns*
- *Small scale processes*





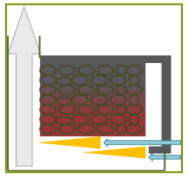
- *The "Green Mad Retort"*
- *Prototypes in Madagascar*
- *Is based on the same principle as the Adam retort*
- *Sealing characteristics of the charcoal chamber have been improved by double walls*
- *The heat from combustion of pyrolysis gas is not recovered neither*
- *Mass yields of 35 % have been recorded*

ural Research Center – CRA-W
ass, Bioproducts & Energy
mmerman – temmerman@cra.wallonie.be

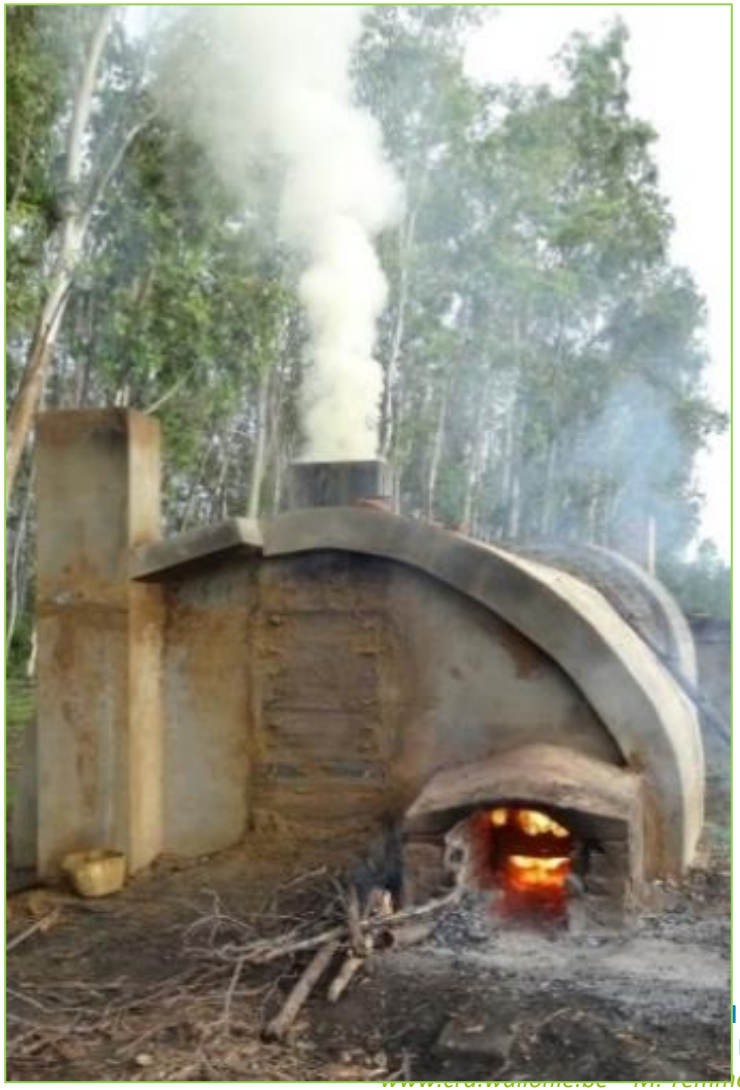
Wallonie

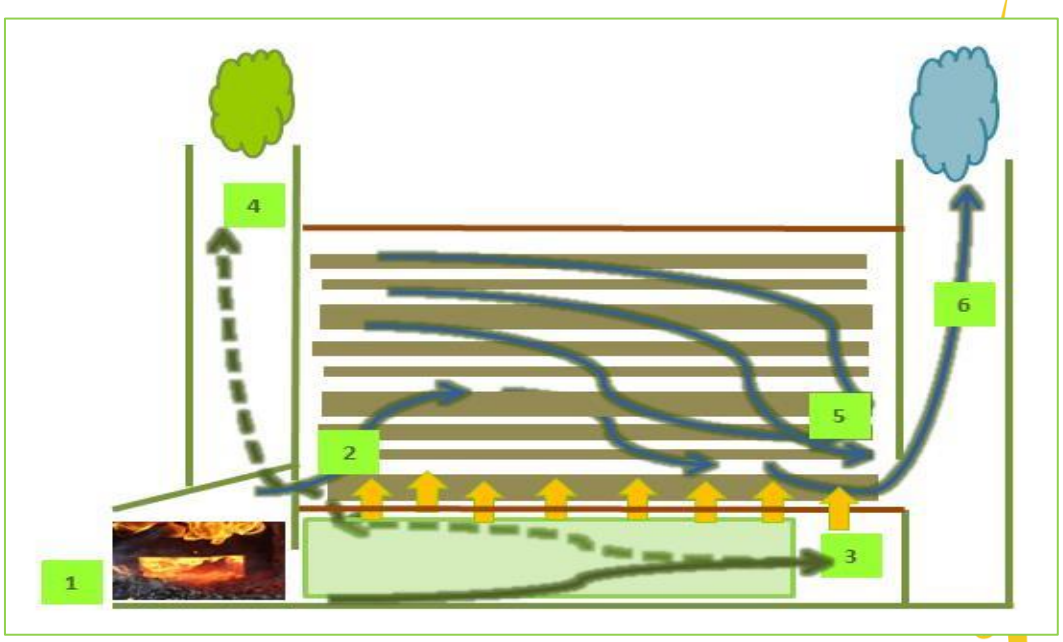
Improvement of charcoal production yields

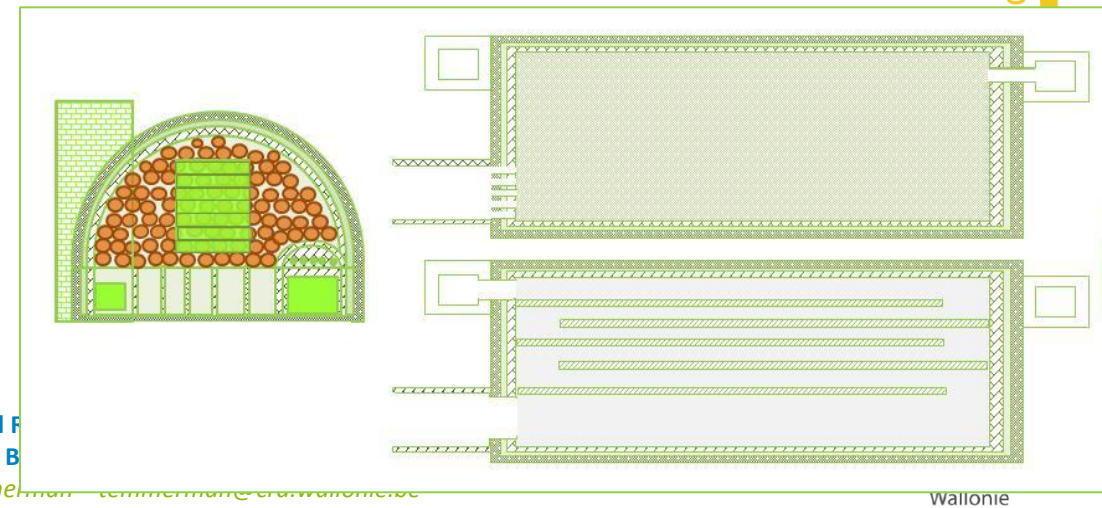
- *Retort Kilns*



- *Small scale processes*

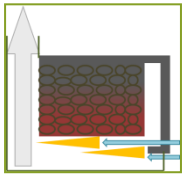




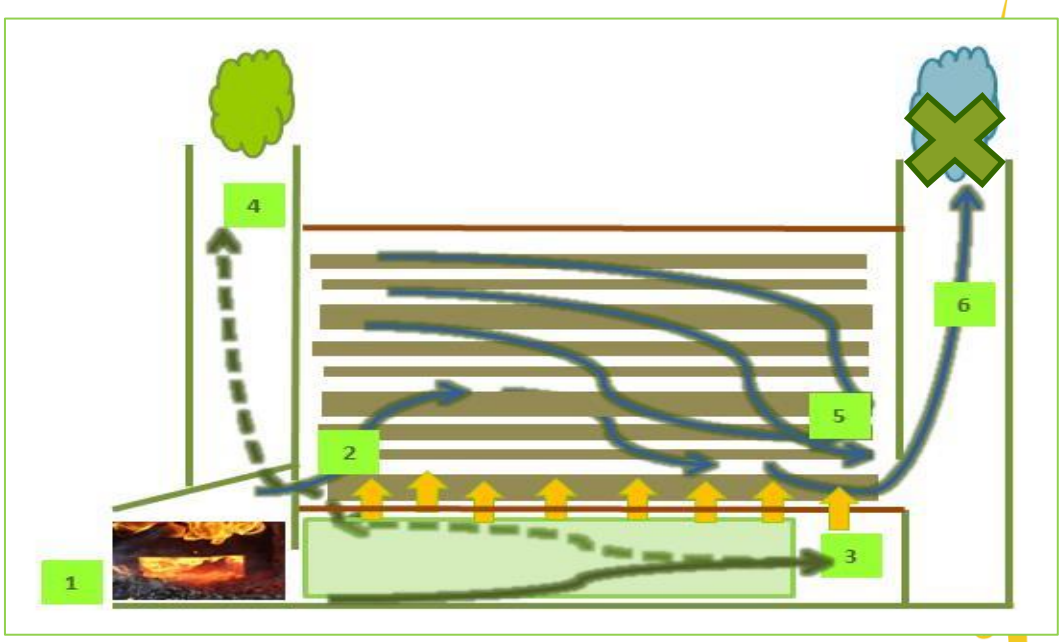


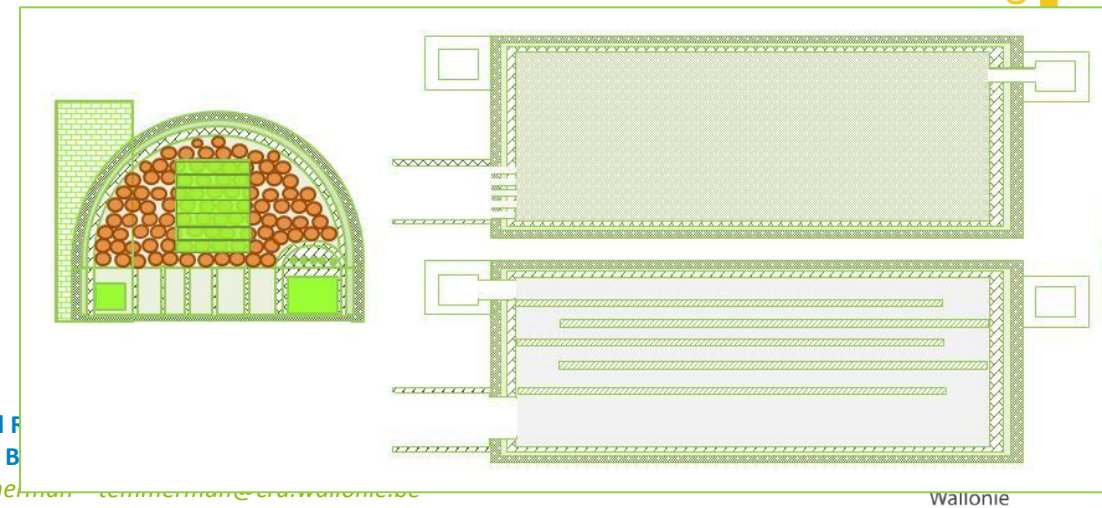
Improvement of charcoal production yields

- *Retort Kilns*



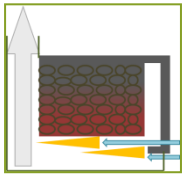
- *Small scale processes*



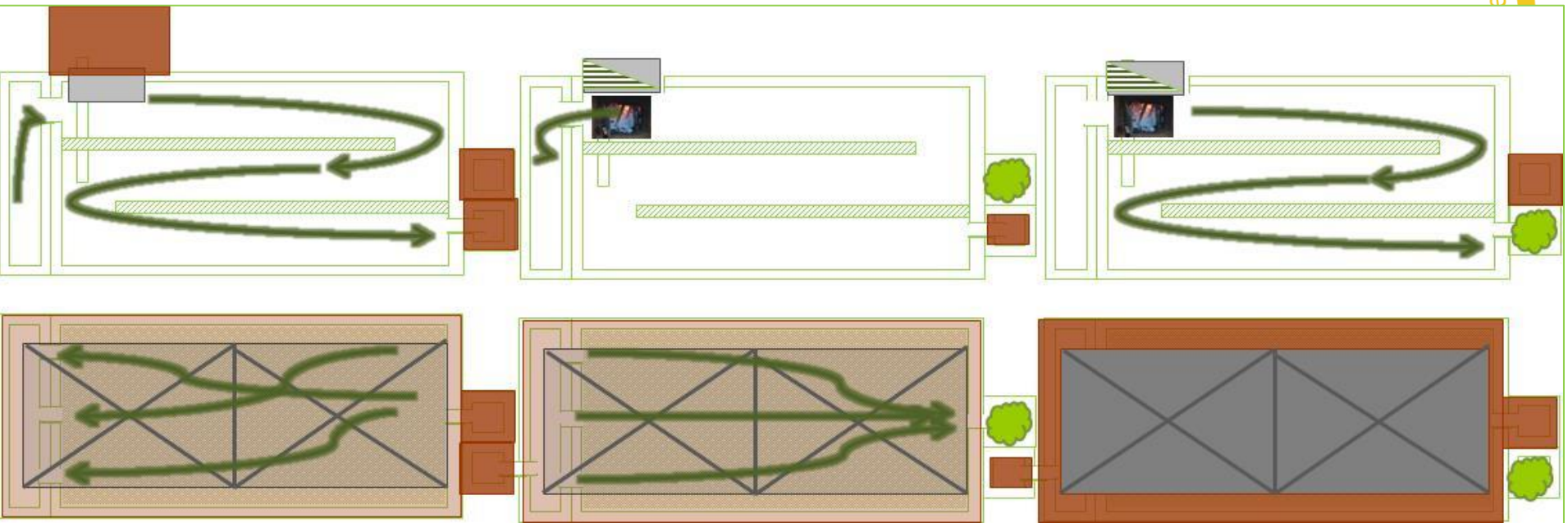


Improvement of charcoal production yields

- *Retort Kilns*

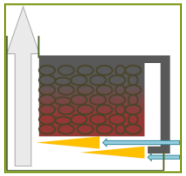


- *Small scale processes*
  - *The "Mindourou Kiln"*
  - *Prototypes in Cameroun*
  - *Is based on the same principle as the Green Mad retort*
  - *Sealing improvements have there been solve by implementing the kiln in a pit*
  - *It is a multi cell kiln*
  - *The heat from combustion of pyrolysis gas is recovered to dry the wood in the next cell of the kiln*
  - *35% Mass yield have been recorded and may still be improved*

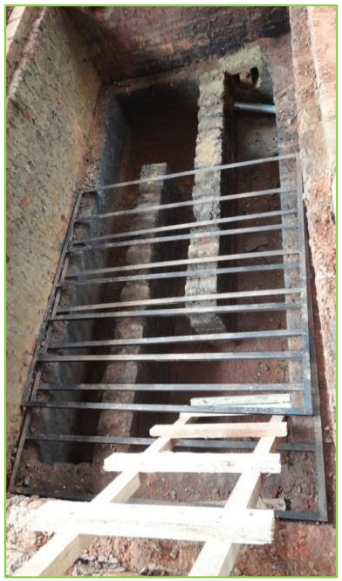


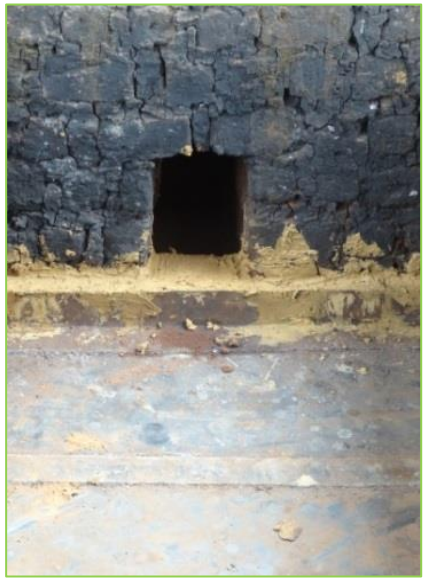
Improvement of charcoal production yields

- *Retort Kilns*
- *Small scale processes*



- *The "Mindourou Kiln"*





on Agricultural Rese
U13 – Biomass, Biopr
e.be – M. Temmerma

Centre wallon de Recherches agronomiques

Wallonie

Improvement of charcoal production yields

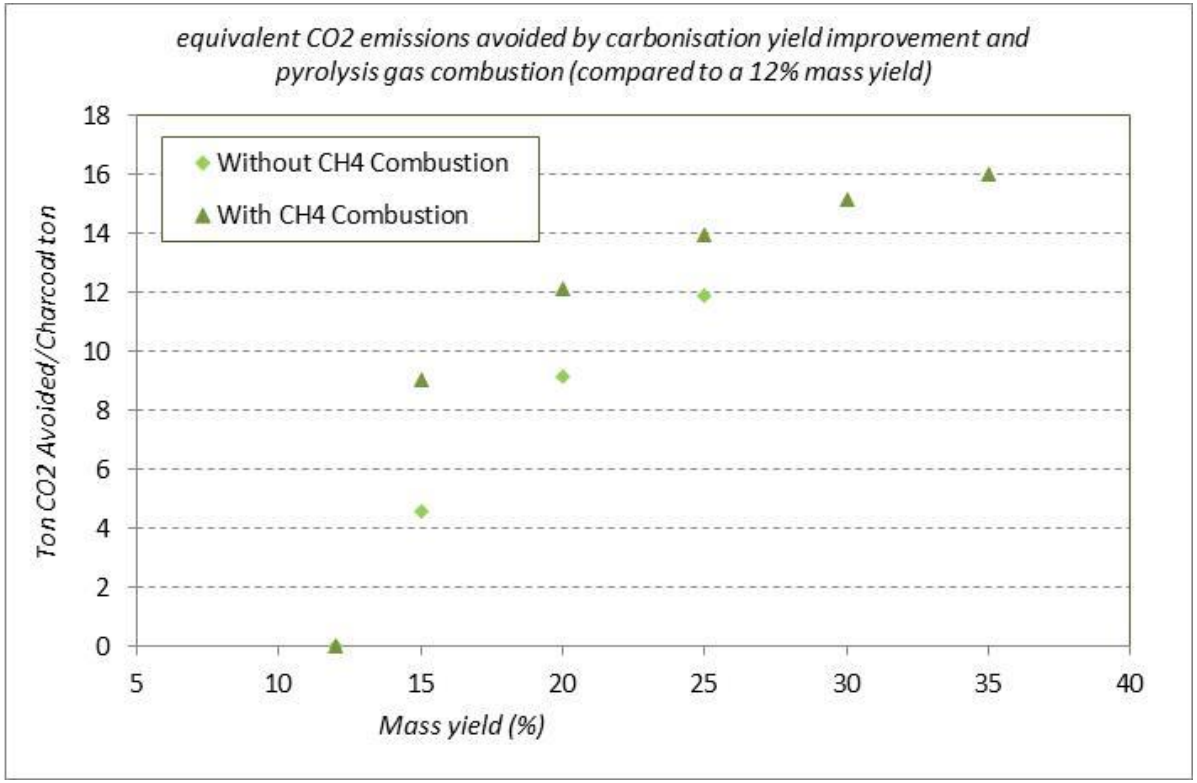
- *Impact of the use of improved charcoal production process*

- *Regarding human health*
  - *Traditional carbonization sites are often smoky due to the use of mound kilns*
  - *The improved processes*
    - *Lead to more complete combustion of pyrolysis gas, which drastically reduce their toxicity*
    - *Are equipped by chimneys which avoid smoke at human height*

Walloon Agricultural Research Center – CRA-W
U13 – Biomass, Bioproducts & Energy
www.cra.wallonie.be – M. Temmerman – temmerman@cra.wallonie.be

Improvement of charcoal production yields

- Impact of the use of improved charcoal production process



- Compared to a low carbonization mass yield of 12%
  - The use of improved process e.g. up to a yield of 20% allows to avoid
    - About 9 Tons CO_2/ton charcoal just due to yield improvement
    - About 12 Tons CO_2/ton charcoal if CH_4 is combusted in a retort kiln
  - Retort kiln allow to reach mass yields of 35%
    - In this case, 16 tons CO_2 / ton charcoal are avoided if compared to a 12% mass yield

- *Improvement of the environmental impact of charcoal production*
  - *The opportunity of using sawmills residues*
  - *Improvement of charcoal production yields*

- ***Improvement of conversion yields***
  - ***Improved stoves***

Walloon Agricultural Research Center – CRA-W
U13 – Biomass, Bioproducts & Energy
www.cra.wallonie.be – M. Temmerman – temmerman@cra.wallonie.be

Improved domestic stoves

- The most used stoves, in many cases remains the three stone fire

- This fire is characterized by
  - Very low Energy efficiency (5 to 10%)
  - High emissions
    - CO
    - CH_4
    - Particulate matter
- Improved fire stoves have been proposed first to decrease the amount of fuel needed for cooking
- Afterwards it has been demonstrated that higher efficiency is linked with lower emissions

Walloon Agricultural Research Center – CRA-W
U13 – Biomass, Bioproducts & Energy
www.cra.wallonie.be – M. Temmerman – temmerman@cra.wallonie.be

Improved domestic stoves

- Lots of improved stoves have been proposed

- Metal made stoves
- Clay made stoves
- Rocket stoves
- With or without chimney
- …

- All characterized by some advantages:
  - Affordable or expensive
  - Mobile or fix
  - Mono or multi pan
  - Easy to use or not
  - Leading to fuel savings
  - Useful for traditional cooking
  - …

- It appears the best efficiency is reached with stoves adapted to the pan
  - With is against the users who want to use different pans on the same stove
- Several stoves allow to reach better performance compared to the 3 stones fires
  - But efficiency generally remains low (10 to 25%)
  - The efficiency development is limited by the price of the stove

Improved domestic stoves

- Selected stoves have been promoted by national & international institutions
- For example

- Roumdé stove in Burkina Faso

- Sakkannal in Sénégal

- Djambar in Sénégal

- New tree Stoves
- Burkina Faso

- Rocket Stoves

Walloon Agricultural Research Center – CRA-W
U13 – Biomass, Bioproducts & Energy
www.cra.wallonie.be – M. Temmerman – temmerman@cra.wallonie.be

Conclusions

- *Domestic energy efficiency in Africa still may be improved as well as on its impact on human health, as for its environmental impact*

- *Simple & clean carbonization process have recently been set up*

  - *These small scale retort kilns allow high efficiencies and when compared to low yield traditional carbonization techniques allow to save about 16 ton CO_2/ton charcoal*

  - *The probably low level of investment of these processes are another point that could contribute to a large spreading of these techniques*

- *Some improved stoves allow significant fuel savings and a significant decrease of emissions associated to domestic cooking*

  - *These stove have generally been, and are still promoted at national levels*
  - *Nevertheless efficiency of domestic stoves remains low and could be improved, if the price of these stove could increase*
  - *But the acceptance of improved stoves always has to face the purchasing power of users*

Walloon Agricultural Research Center – CRA-W
U13 – Biomass, Bioproducts & Energy
www.cra.wallonie.be – M. Temmerman – temmerman@cra.wallonie.be

Thank you

Walloon Agricultural Research Center – CRA-W
U13 – Biomass, Bioproducts & Energy
www.cra.wallonie.be – M. Temmerman – temmerman@cra.wallonie.be

cra-w

Centre wallon de Recherches agronomiques

Wallonie