

Enhancing food security and nutrition in Africa: Flash dryer

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ON BEHALF OF THE POSTHARVEST QUALITY LAB,
CASSAVA PROGRAM

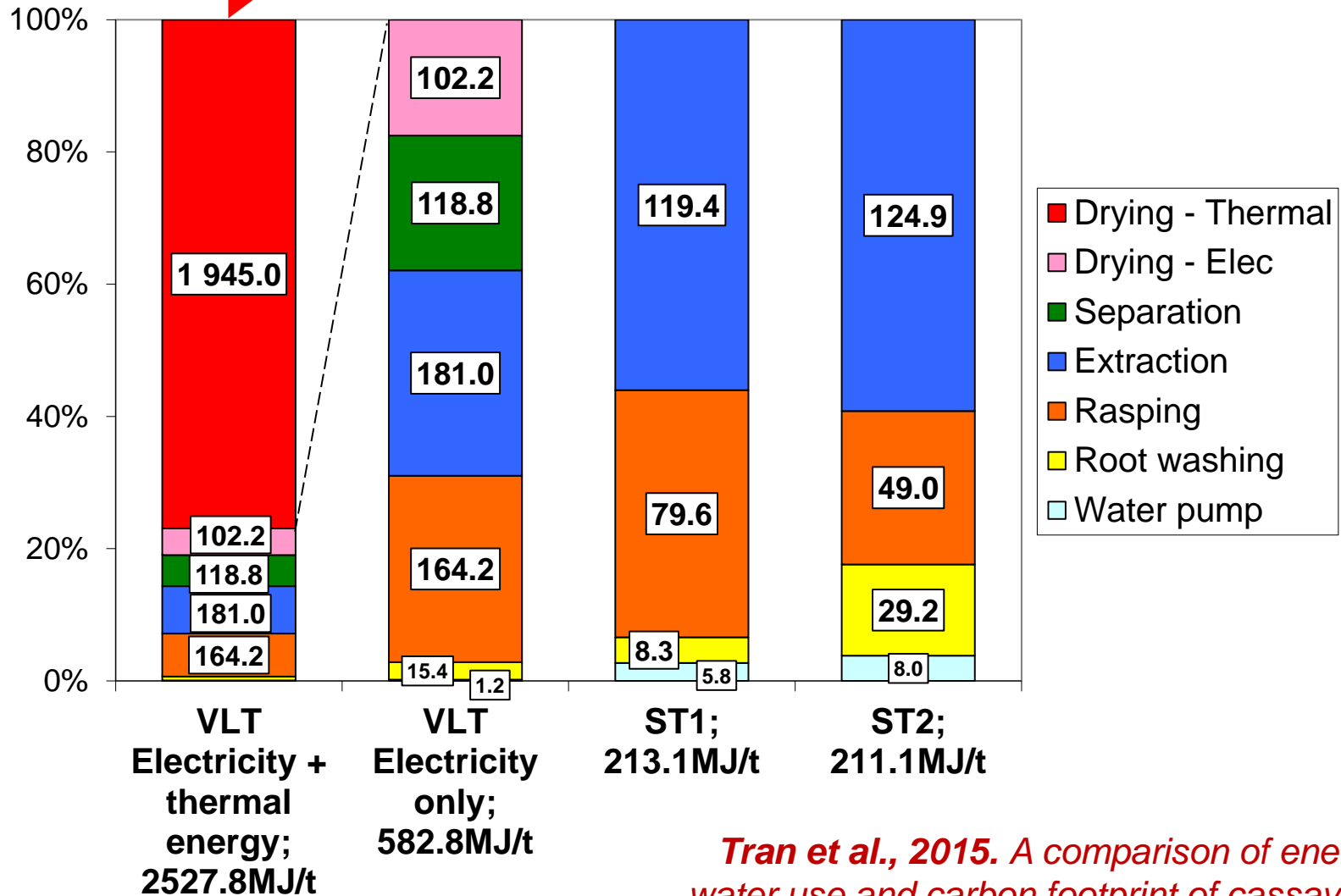
CASSAVA RETREAT, CIAT PALMIRA, 14/02/2023



RESEARCH
PROGRAM ON
Roots, Tubers
and Bananas



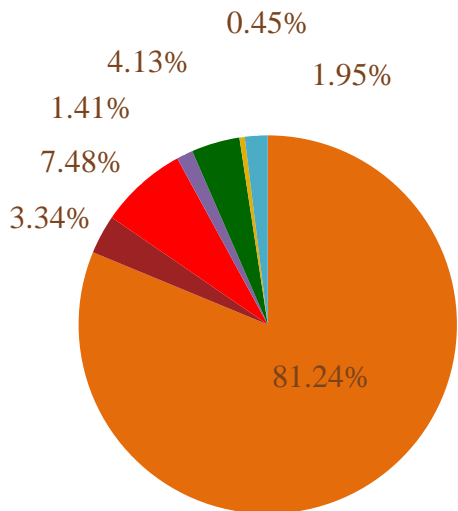
Drying represents 70-80% of energy use for cassava starch or flour



Tran et al., 2015. A comparison of energy use, water use and carbon footprint of cassava starch production in Thailand, Vietnam and Colombia

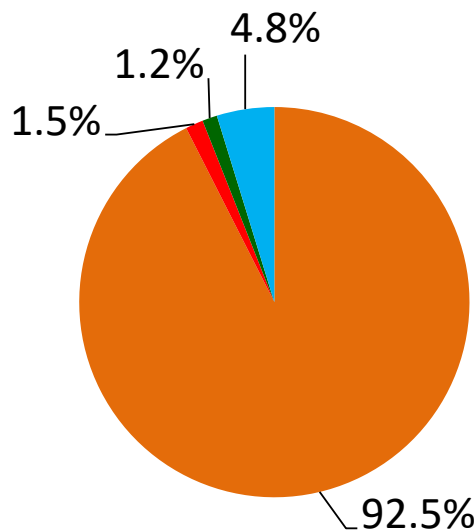
Energy represents 7-20% of production costs

Thailand

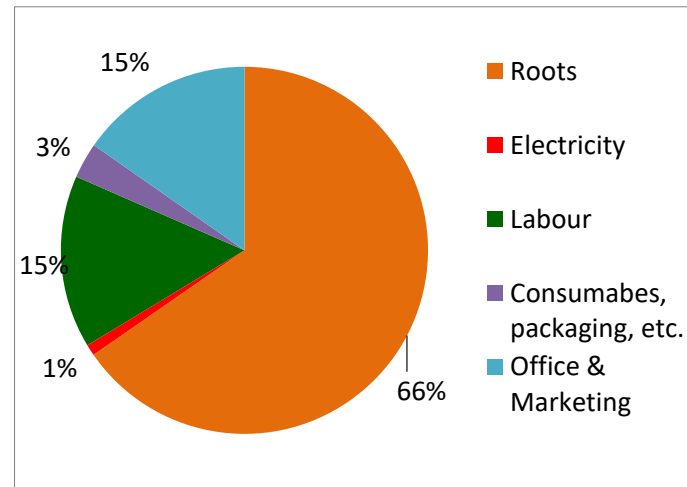


Vietnam

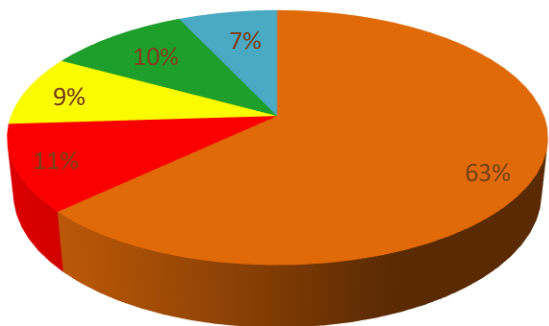
PA1



Colombia

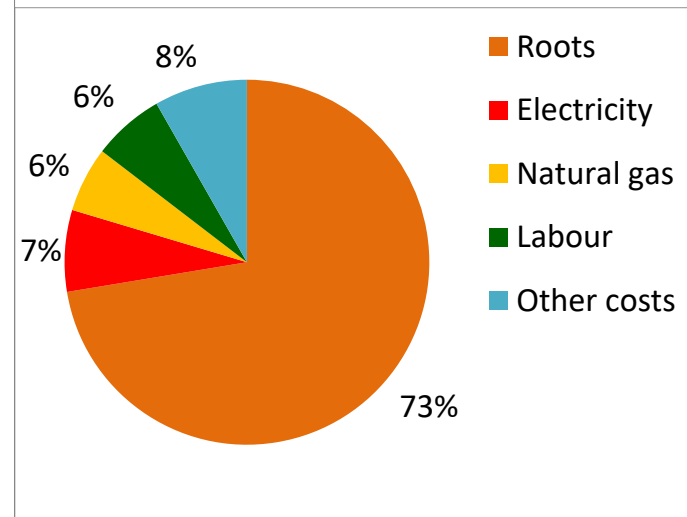


Nigeria

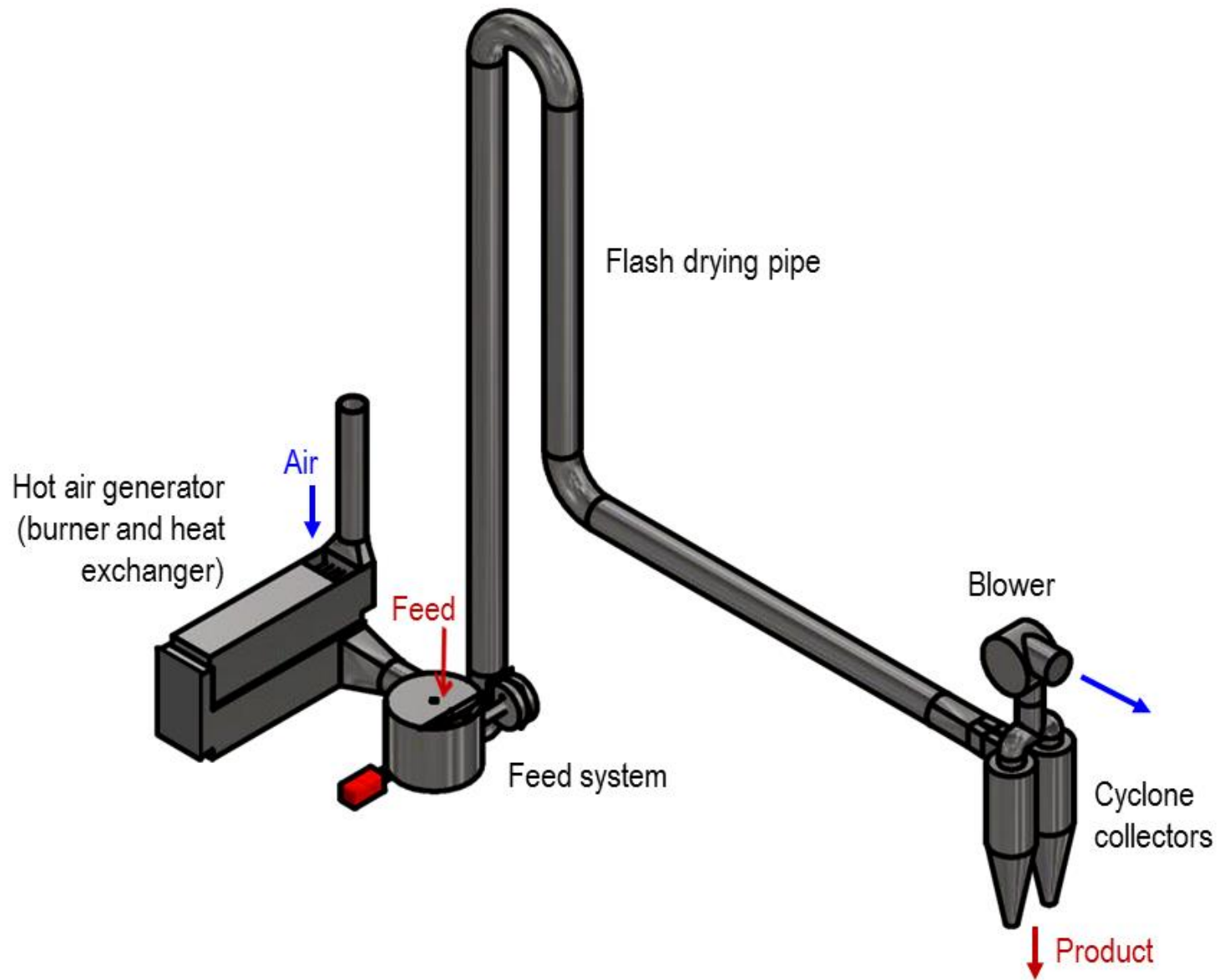


2nd highest cost after cassava roots

- Raw material
- Power
- Energy (drying)
- Labour
- Packaging



Key components of a flash dryer



No consensus on the design of flash dryers

- Pipe length: 15 – 60 m
- Temperature: 130 – 180°C
- Air velocity: 10 – 25 m/s
- Diversity of shapes of the drying tube



Diversity of dryers shapes and operating conditions

Nigeria



2-4 t starch/day



Diversity of dryers shapes and operating conditions

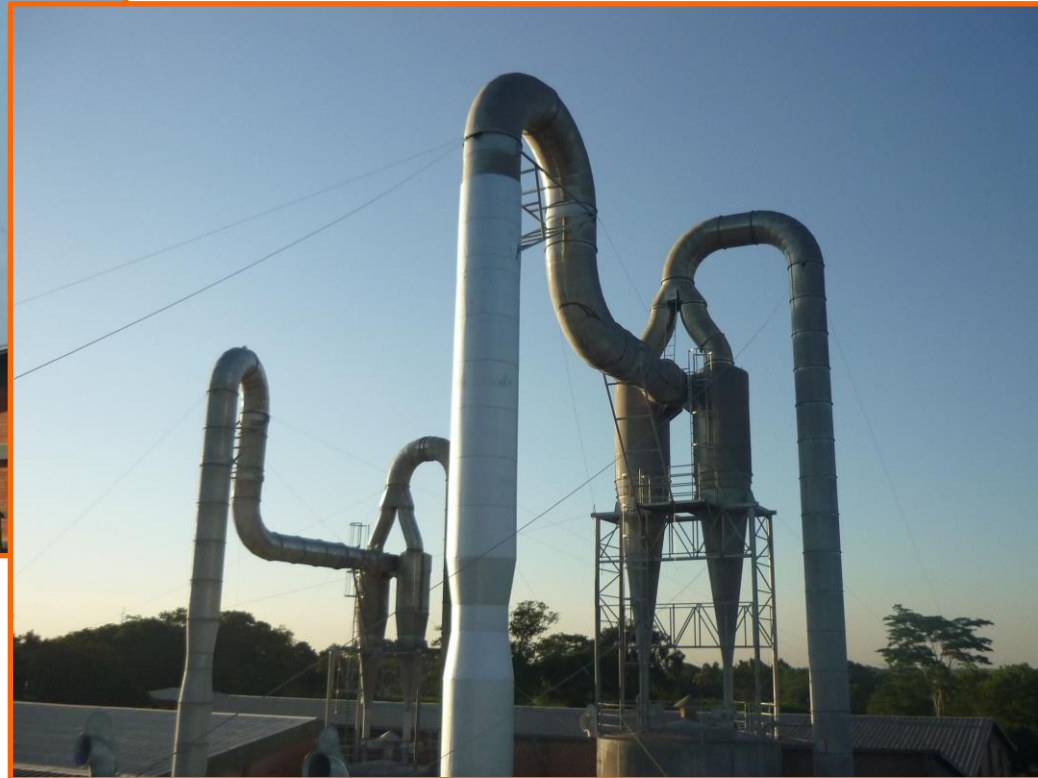
Thailand

conditions



Diversity of dryers shapes and operating conditions

Paraguay (Brazil EBS technology)



*CIRAD, CIAT, Univalle,
Clayuca, KMUTT*

Diversity of dryers shapes and operating conditions



Paraguay (Larsson)

Diversity of dryers shapes and operating conditions

Argentina (S.A.1)



Diversity of dryers shapes and operating conditions



**Argentina
(S.A.2)**

*CIRAD, CIAT, Univalle,
Clayuca, KMUTT*

Diversity of dimensions

| | unit | C-III | C-IV | C-II | TH-1 | TH-2 | TH-3 |
|---------------|----------------|-----------|-------------|-----------|-------------|-----------|-----------|
| Pipe up | m | 26 | 12 | 18 | 37.6 | 25 | 23 |
| Pipe down | m | 7 | 8.7 | - | 20.1 | 20 | 23 |
| Pipe under | m | - | - | 35 | - | - | - |
| Total length | m | 33 | 20.7 | 53 | 57.7 | 45 | 46 |
| Δ diameter | m | no | yes | yes | yes | no | no |
| Diameter up | m | 1.2 | 1.5 | 1.0 | 1.5 | 1.14 | 1.16 |
| Diameter down | m | 1.2 | 0.95 | 0.71 | 1.94 | 1.14 | 1.16 |
| Capacity | kg starch db/s | 1.1 | 1.0 | 0.5 | 4.4 | 2.0 | 1.8 |

Small scale dryers: 5 – 12m

Diversity of designs → Is there an optimum?

Diversity of operating conditions

| | unit | C-III | C-IV | C-II | TH-1 | TH-2 | TH-3 |
|---------------|----------------|-------------|-------------|-------------|-------------|-------------|------------|
| Capacity | kg starch db/s | 1.1 | 1.0 | 0.5 | 4.4 | 2.0 | 1.8 |
| Air flow | kg air/s | 27.6 | 21.8 | 20.4 | 35.6 | 19.8 | 12.7 |
| A/S ratio | | 25.1 | 21.8 | 40.8 | 8.1 | 9.9 | 7.1 |
| T°in | °C | 130 | 155 | 135 | 175 | 170 | 173 |
| T°out | °C | ~60 | ~60 | ~60 | 55 | 54 | 52 |
| Starch mc in | %wwb | 33 | 40 | 36 | 36 | 35 | 34 |
| Starch mc out | %wwb | 13 | 13 | 13 | 13 | 13 | 14 |
| Energy use | MJ/t starch | 2047 | 2225 | 3400 | 1266 | 1248 | 931 |
| Energy use | MJ/t water | 5841 | 4807 | 8000 | 3091 | 3687 | 3071 |
| Energy eff | % | 41 | 50 | 30 | 79 | 66 | 79 |

- .
- .

Small-scale flash dryers use more energy

25 - 30 USD/t
42 - 100 USD/t

| | Capacity t/day | Energy use MJ/t starch | Energy type |
|------------------|-------------------|---------------------------|---------------|
| Thailand | 200 | 1500 - 2000 | Biogas |
| Vietnam | 2 | 5000 | Coal |
| Nigeria | 1 - 2 | 3000 - 10000 | Oil / Biomass |
| Paraguay | 25 - 100 | 2000 - 3400 | Wood |
| Colombia (AdS) | 50 | 2600 | Natural gas |
| Colombia (Cauca) | 2 | - | Sun drying |

Can we make dryers at small scale with same energy efficiency as large scale?

Timeline of the flash drying project

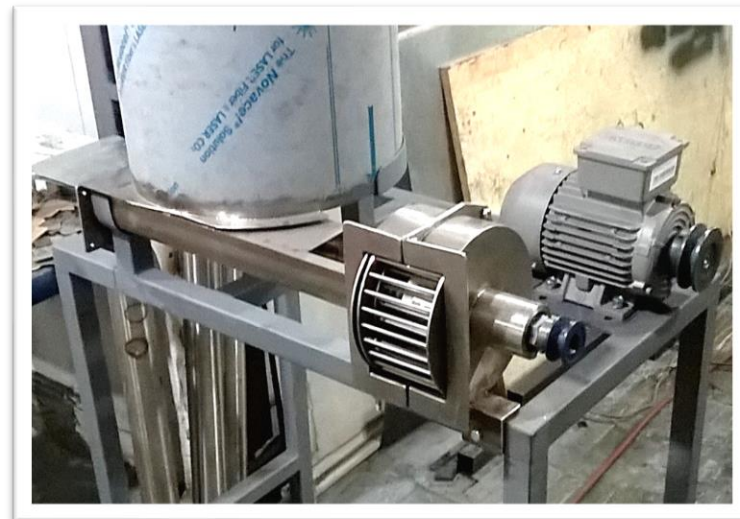
2014-2015: Computer model

2015-2016: Design and construction of prototype at CIAT

2017-2018: Testing and validation of high energy efficiency

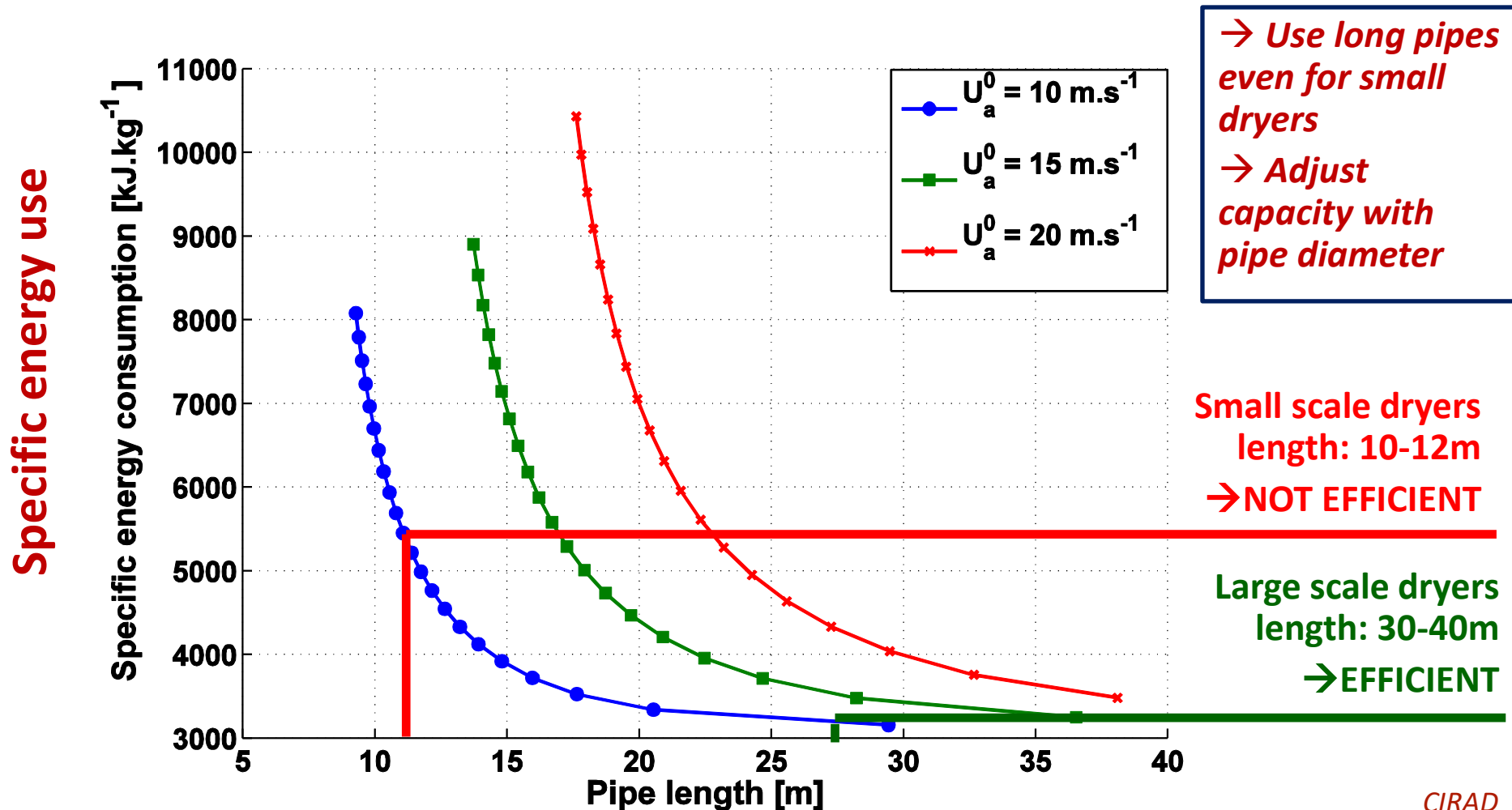
→ 2019-2022: Transfer to private sector (scaling out)

- Reduce energy costs and production costs
- Increase production capacity
- Lower environmental impacts & more sustainable cassava processing



Energy efficiency is possible at small-scale

Model predicts that longer tube reduces energy use. **Min 20 m.**



Key finding: Longer drying tube



Particles stay long enough for optimum heat and water transfers between air and particles.

→ Residence time 1.5 to 2 s

Constraint: Min velocity 10-12 m/s to keep the particles in suspension

Pipe is long enough to ensure correct residence time. → Min 20 m; optimum 25-30 m

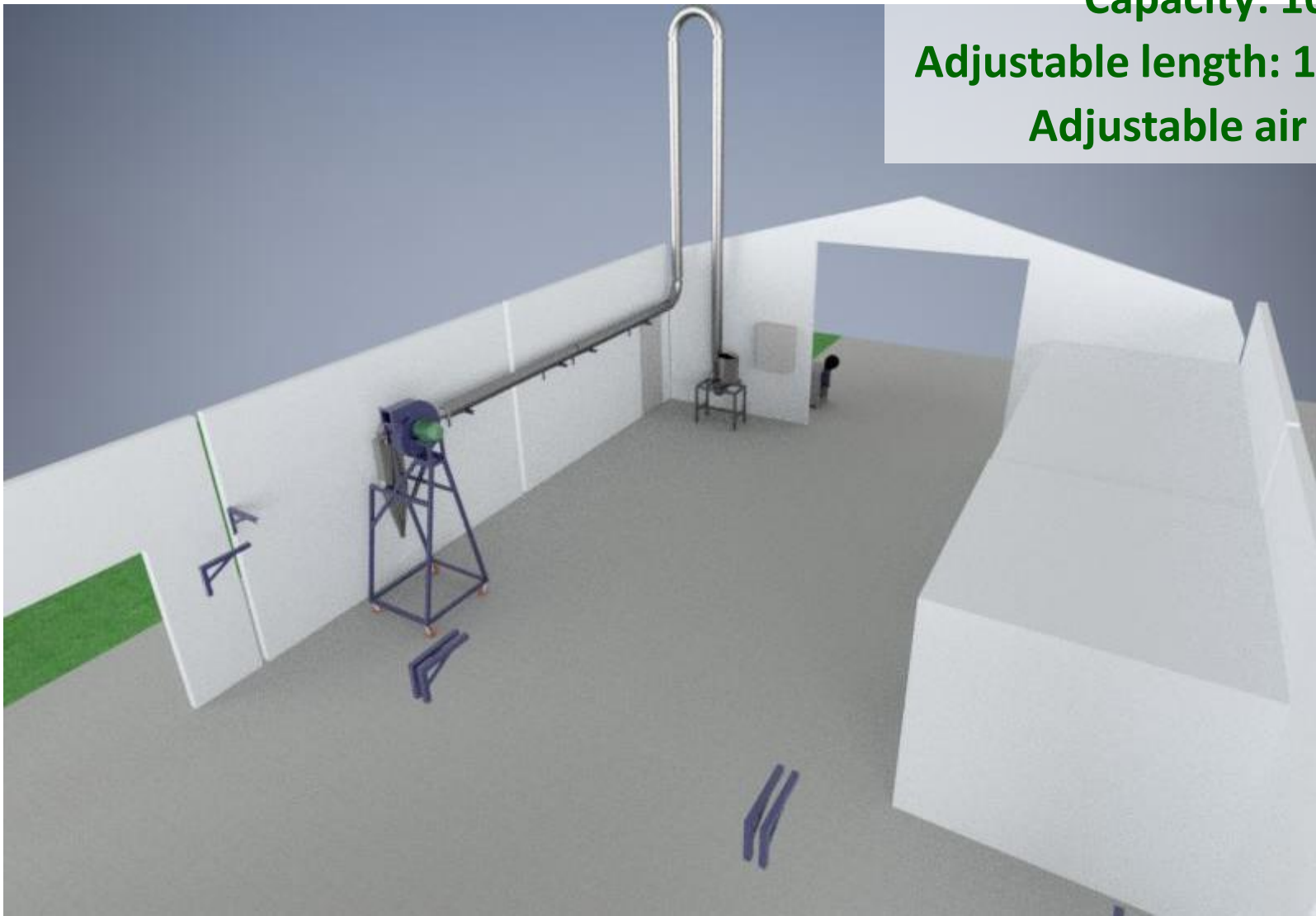
Adjust capacity with the tube diameter.

Max 180-210° C to avoid burning the product.

The pilot flash dryer developed at CIAT

- Equipment layout: Adjustable drying duct length

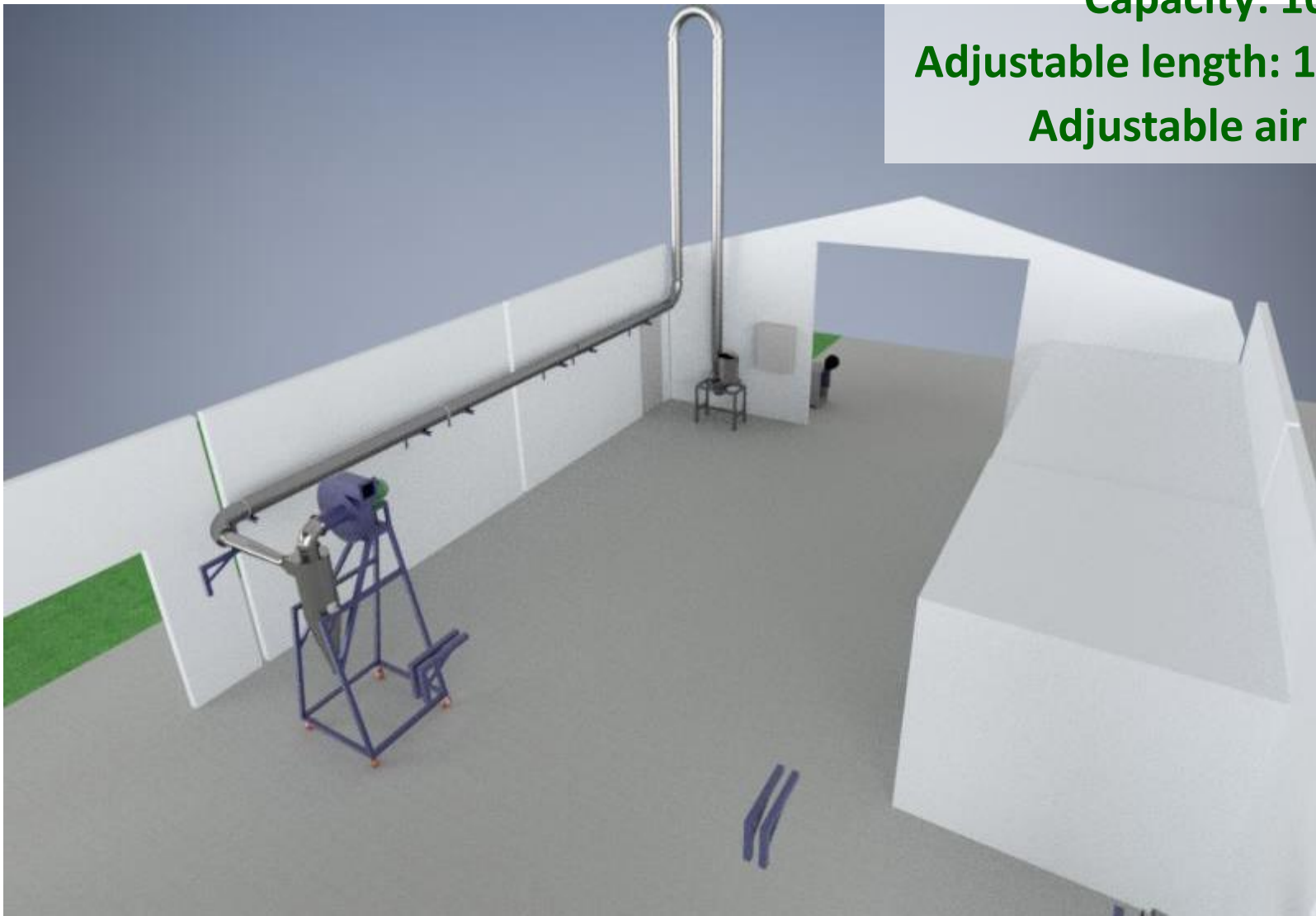
Capacity: 100 kg/hr
Adjustable length: 15 – 35m
Adjustable air velocity



The pilot flash dryer developed at CIAT

- Equipment layout: Adjustable drying duct length

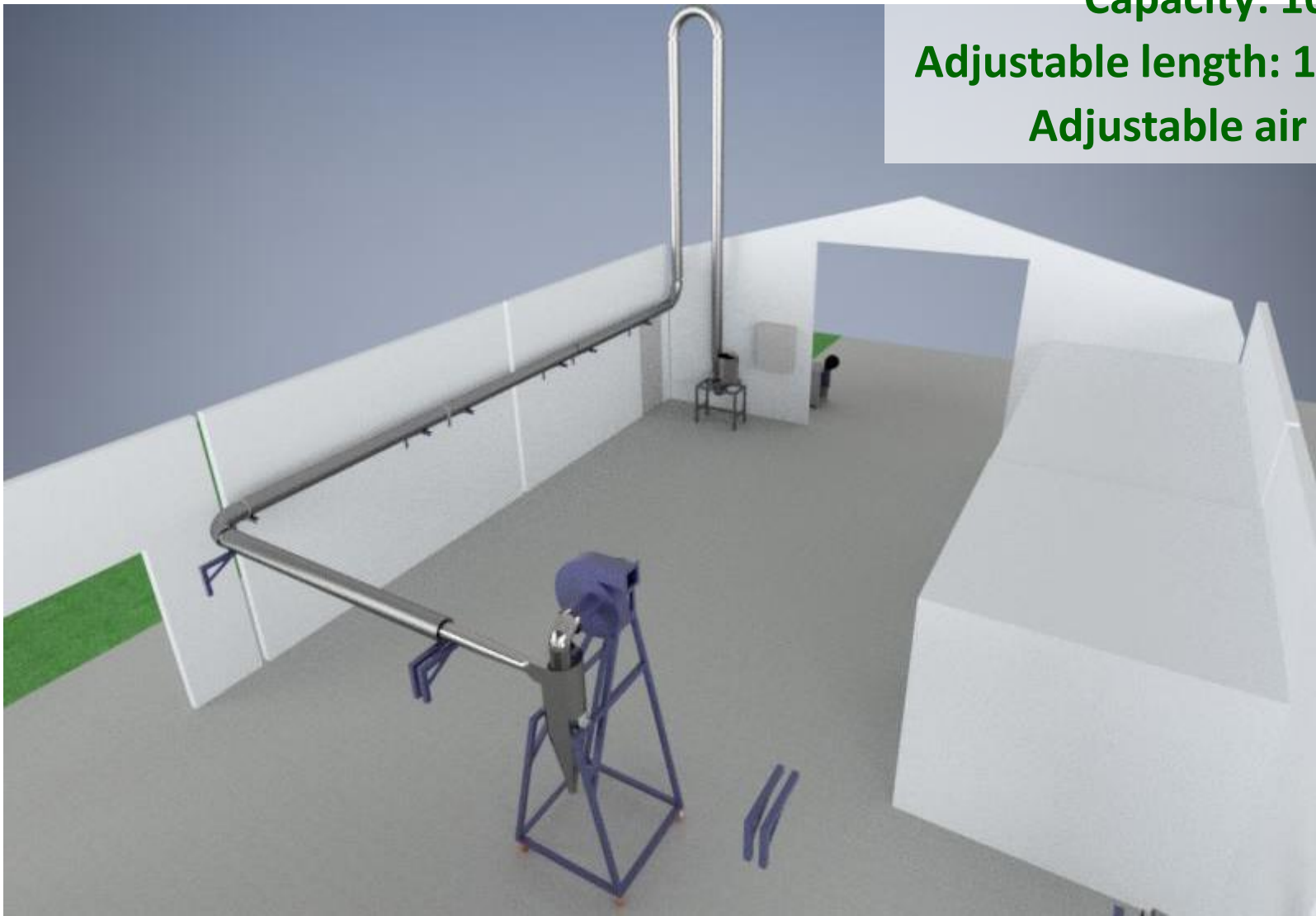
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The pilot flash dryer developed at CIAT

- Equipment layout: Adjustable drying duct length

Capacity: 100 kg/hr
Adjustable length: 15 – 35m
Adjustable air velocity



Pilot at CIAT: Energy efficient, small-scale flash dryer

Adjustable temperature: 120 - 200°C

LPG gas consumption: 3-4 kg/h at 180°C

Cost: 4 USD/h or 0.04 USD/kg starch

Energy: 1500-2000 MJ/t starch
similar to large scale dryers



Drying experiments: results

■ Cassava flour

Effect of pipe length:

| Pipe length (m) | 19 | 26 | 32 |
|------------------------|------|------|------|
| Air velocity (m/s) | 12 | 12 | 12 |
| Temperature (°C) | 192 | 205 | 206 |
| Feed rate (kg/h) | 52 | 64 | 57 |
| Output moisture (% wb) | 18.4 | 15.6 | 11.3 |

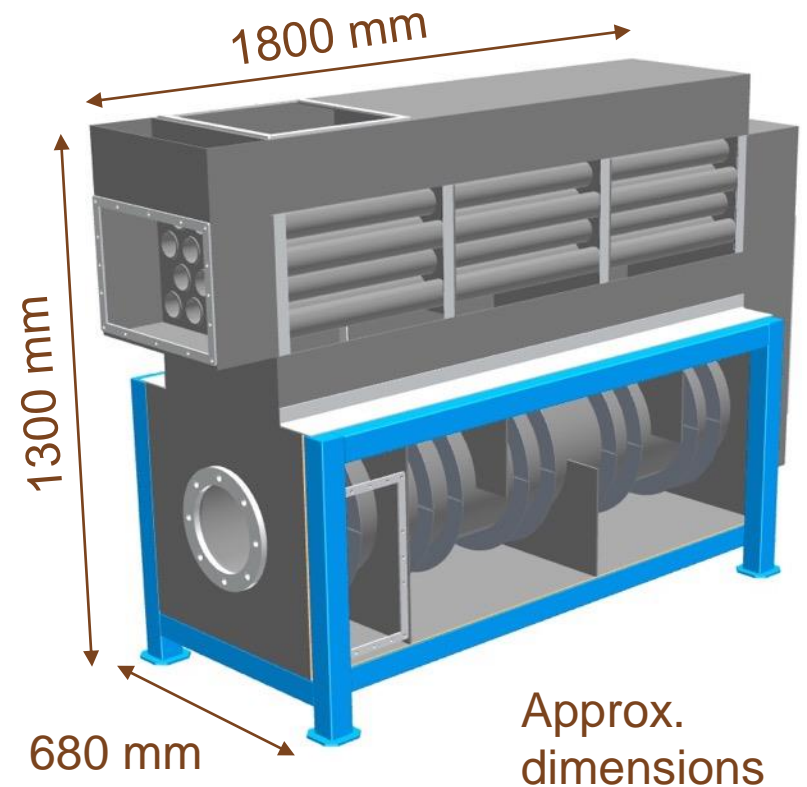
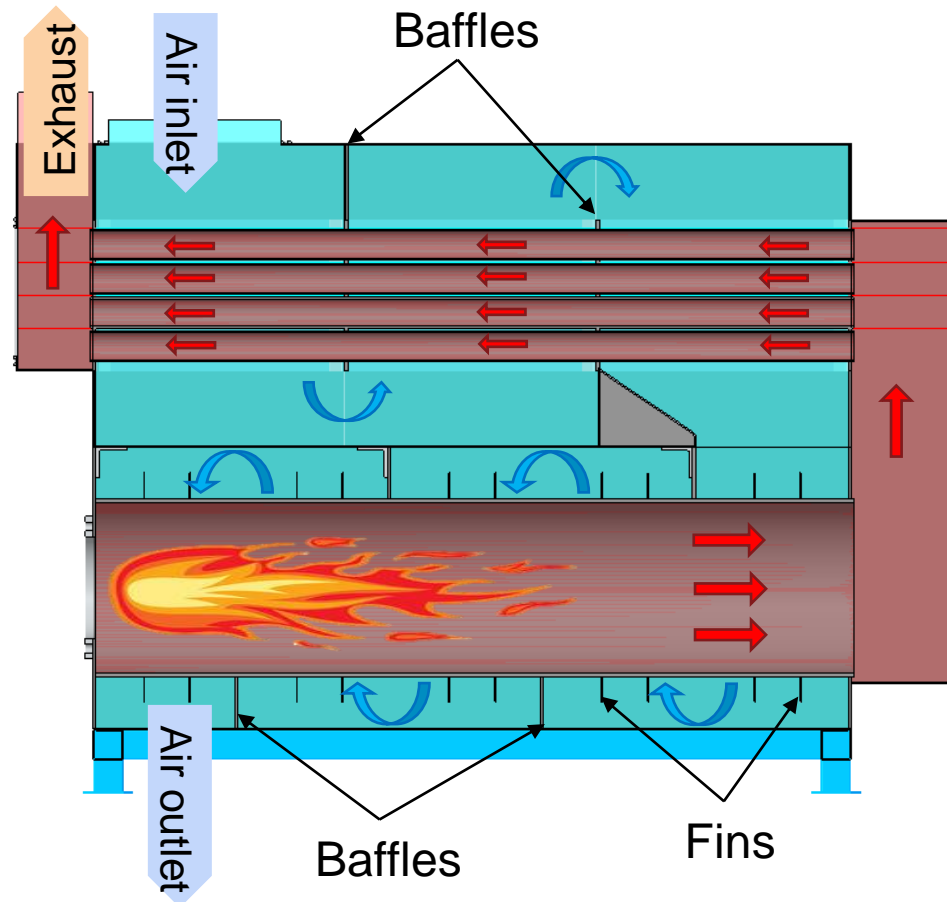
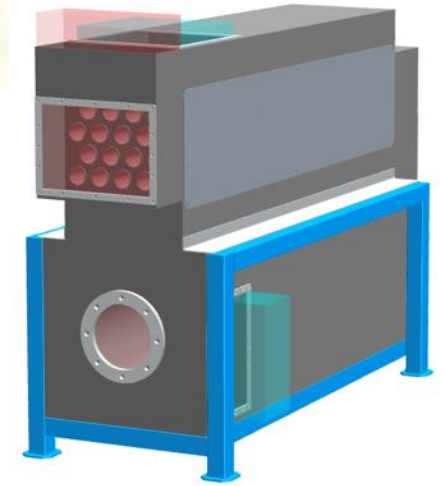
Effect of other parameters:

| Pipe length (m) | 26 | 26 | 26 | 26 | 32 | 32 |
|------------------------|------|------|------|------|------|------|
| Air velocity (m/s) | 10 | 10 | 10 | 12 | 12 | 12 |
| Temperature (°C) | 180 | 180 | 205 | 205 | 206 | 205 |
| Feed rate (kg/h) | 41 | 46 | 47 | 64 | 57 | 53 |
| Output moisture (% wb) | 11.2 | 12.6 | 10.7 | 15.6 | 11.3 | 10.7 |

Additional component: Heat exchanger design

- Design proposal

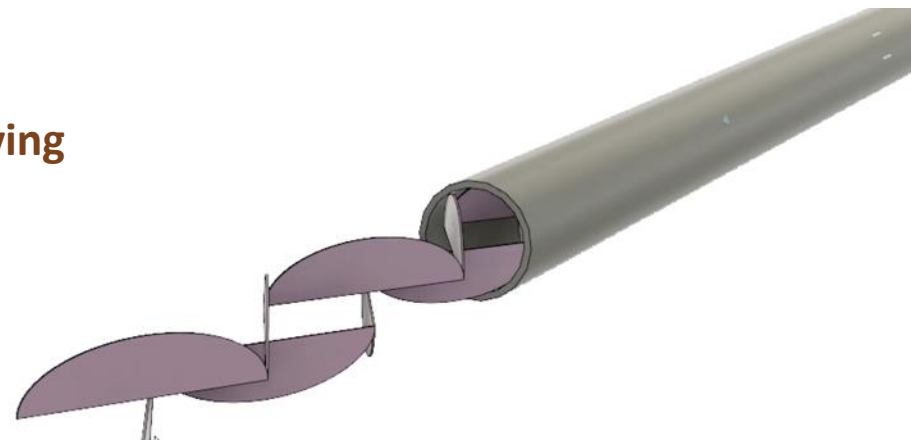
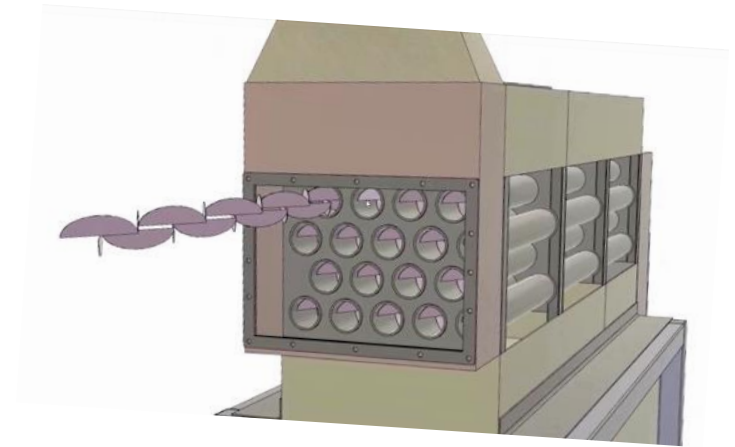
- Example of a 60 kW hot air generator producing air at 210 °C



Additional components for flash drying system efficiency

Heat exchanger design

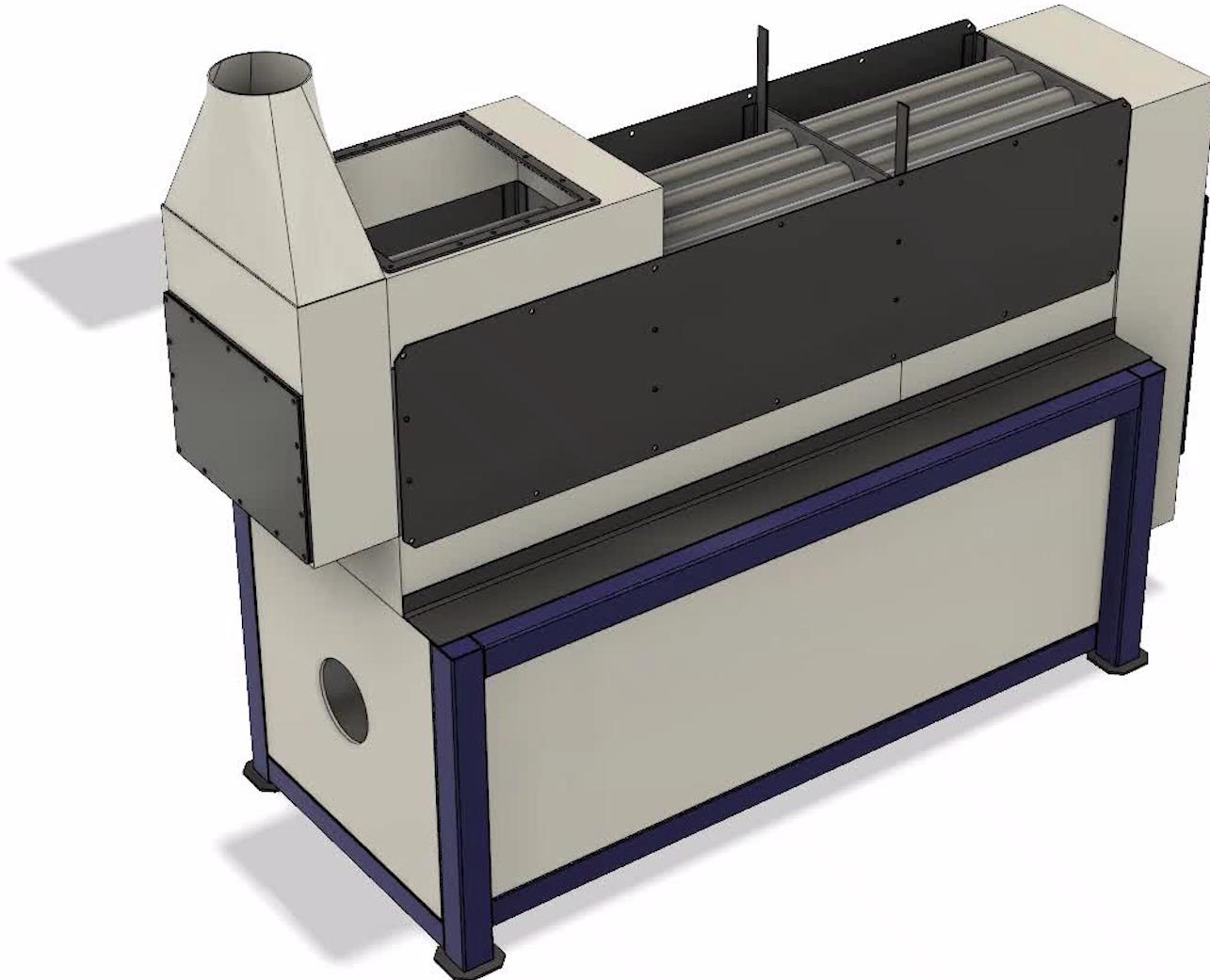
- **Design proposal**
 - Example of a 60 kW hot air generator producing air at 210 °C
 - **Turbulators** are placed in the smoke pipe: they increase heat exchange by a factor of 5-10
- **Operation**
 - Choose the **closest burner power**
 - **Control:** modulating burner + PID temperature controller (ideally)
 - **Adjust power by adding or removing turbulators**



Heat exchanger design

- Design proposal: video presentation

Credit: Marcelo Precoppe



Scaling out flash dryer innovations

Drying pipe: Recommended 25 to 30 m

Nutripro (DRC)



Ecosac (DRC)



Hickman (Lagos)



FIIRO (Lagos)



FIIRO (Lagos)

Air velocity: Recommended 10-12 m/s

→ Blower ~ 7-8 kW with negative pressure;

~ 11-13 kW with positive pressure

For production capacity 200-300 kg flour/h



Nutripro (DRC)

Scaling out flash dryer innovations

Heat exchanger: Counter-current, thin pipes for high exchange surface, turbulators



Agrimac (DRC)

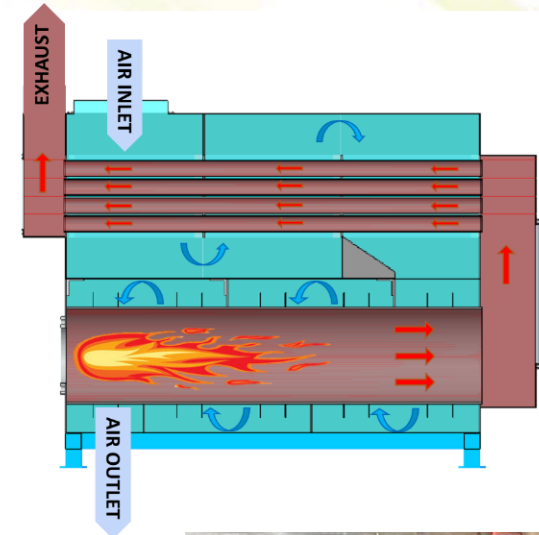


FIIRO (Lagos)



Ecosac (DRC)

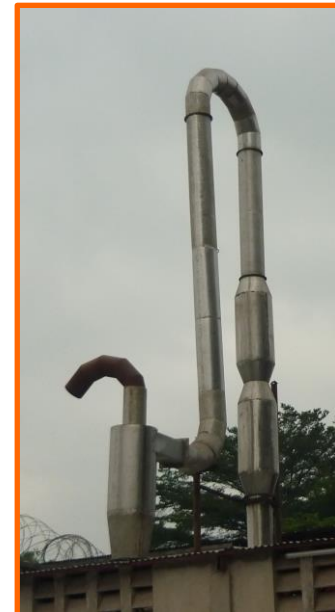
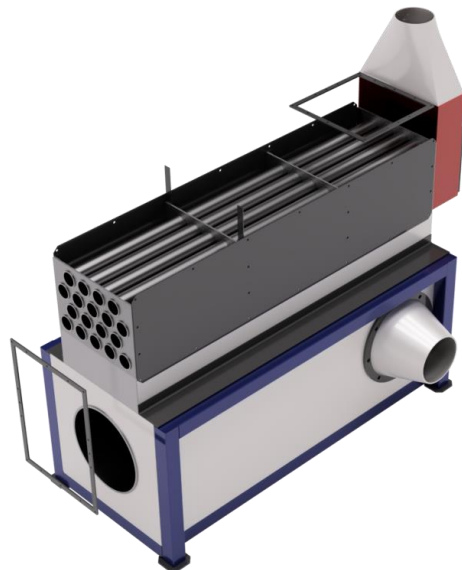
Also one in Ghana



Agrimac (DRC)

Key design criteria for efficient flash dryer

| | Units | Current | Upgraded |
|--|--------------|---------|----------|
| 1. Tube length | m | 7 - 12 | 25 - 30 |
| 2. Blower speed | m/s | 3 - 5 | 10 - 12 |
| 3. Heat exchanger <i>Surface of exchange, turbulators, insulation</i> | % efficiency | 60 | 80 - 90 |
| 4. Insulation of the drying tube | | No | Yes |



Upgrade to 250 kg flour/h (Nov. 2022)

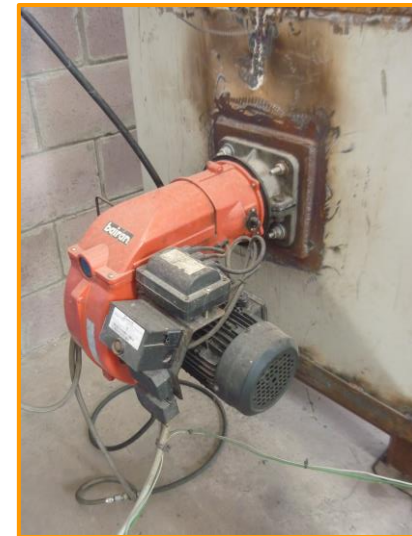
**Nutripro & Agrimac
Kinshasa (DRC)**

Baseline 2019:

- 100 kg/h and 132 L diesel/t flour (5000 MJ/t)

Visit 2022:

- 250 kg/h and 74 L diesel/t flour (2800 MJ/t)





CIAT Centro Internacional de Agricultura Tropical



*Thanks !
Merci !
Gracias !*

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RESEARCH
PROGRAM ON
Roots, Tubers
and Bananas

Alliance

