# Turning Urine into Fertiliser

## Innovative Research for Namibia's Water and Food Security

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# Source-Separation of Domestic Wastewater

**Urine**

Faeces/Brownwater

Greywater

Rainwater

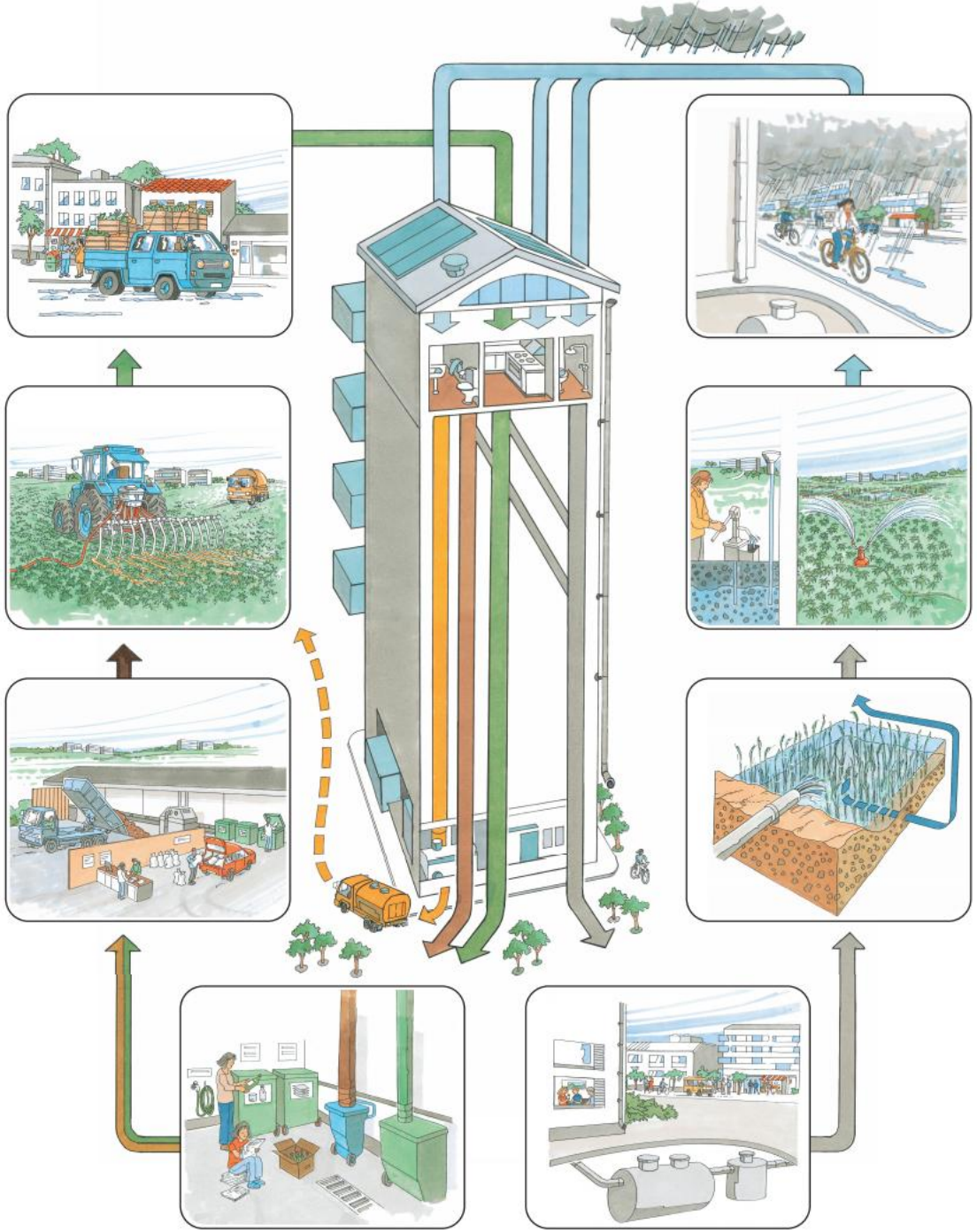
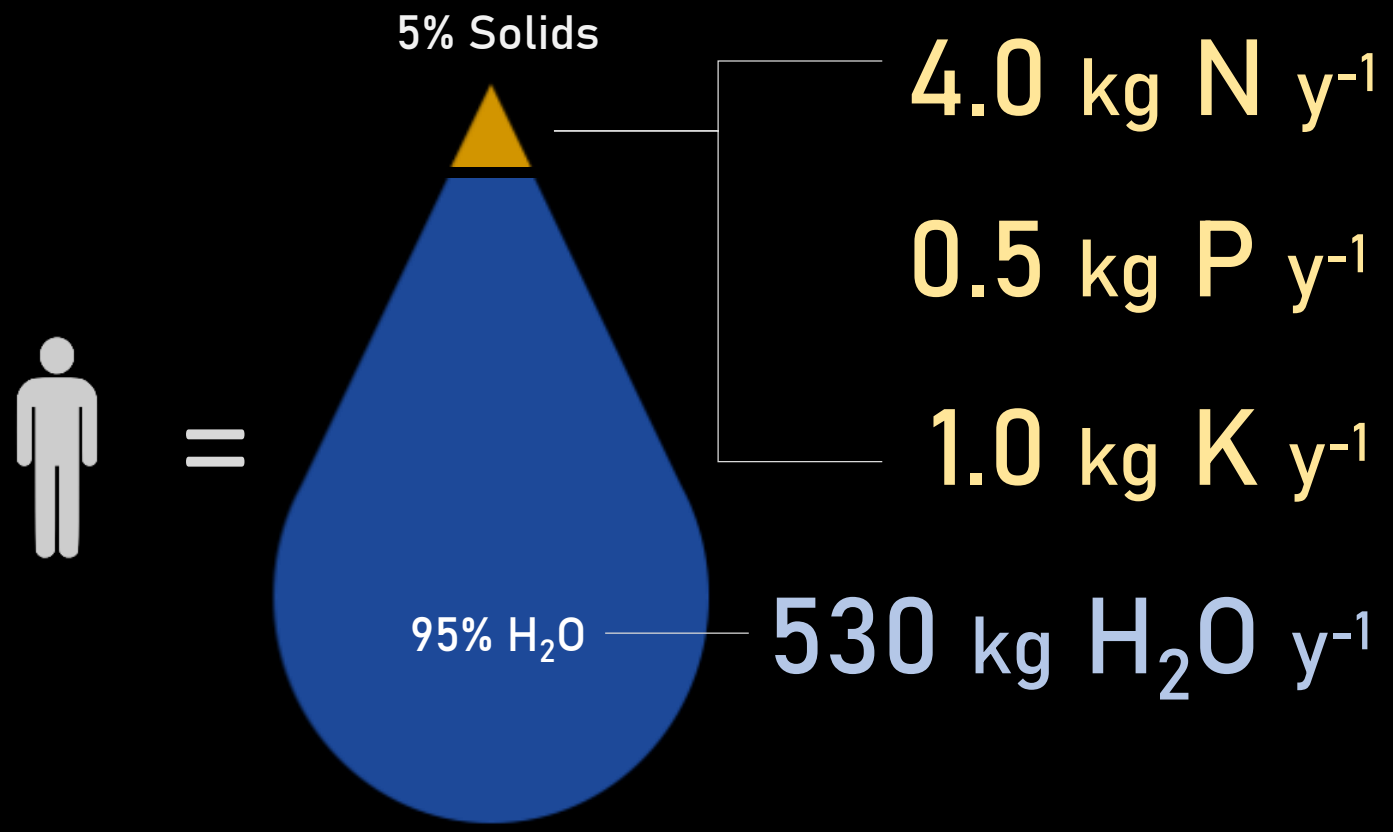


*Image:* EcoSanRes, Stockholm Environment Institute

# Can recycling urine help close society's nutrient loops?

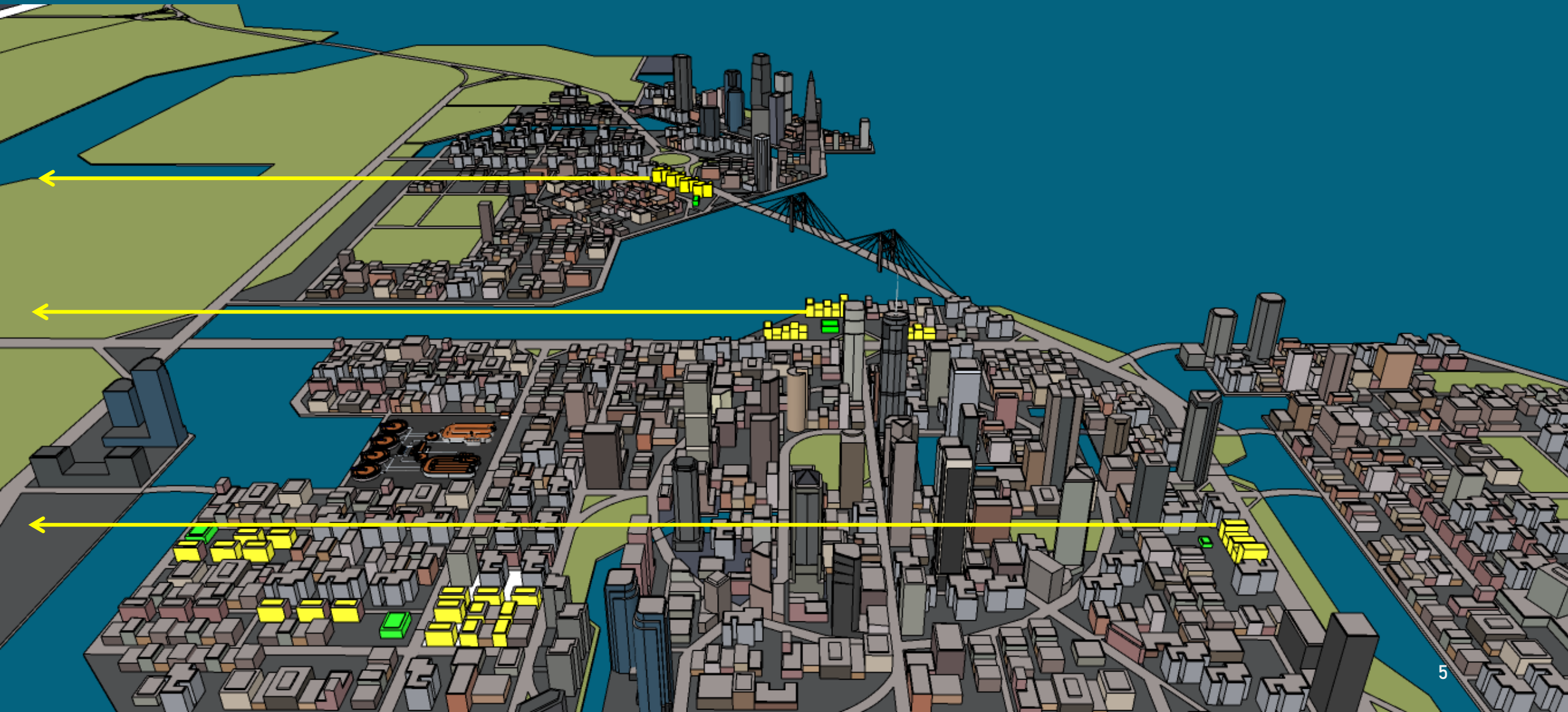

Credit: Marcin Szczepanski.

# URINE COMPOSITION

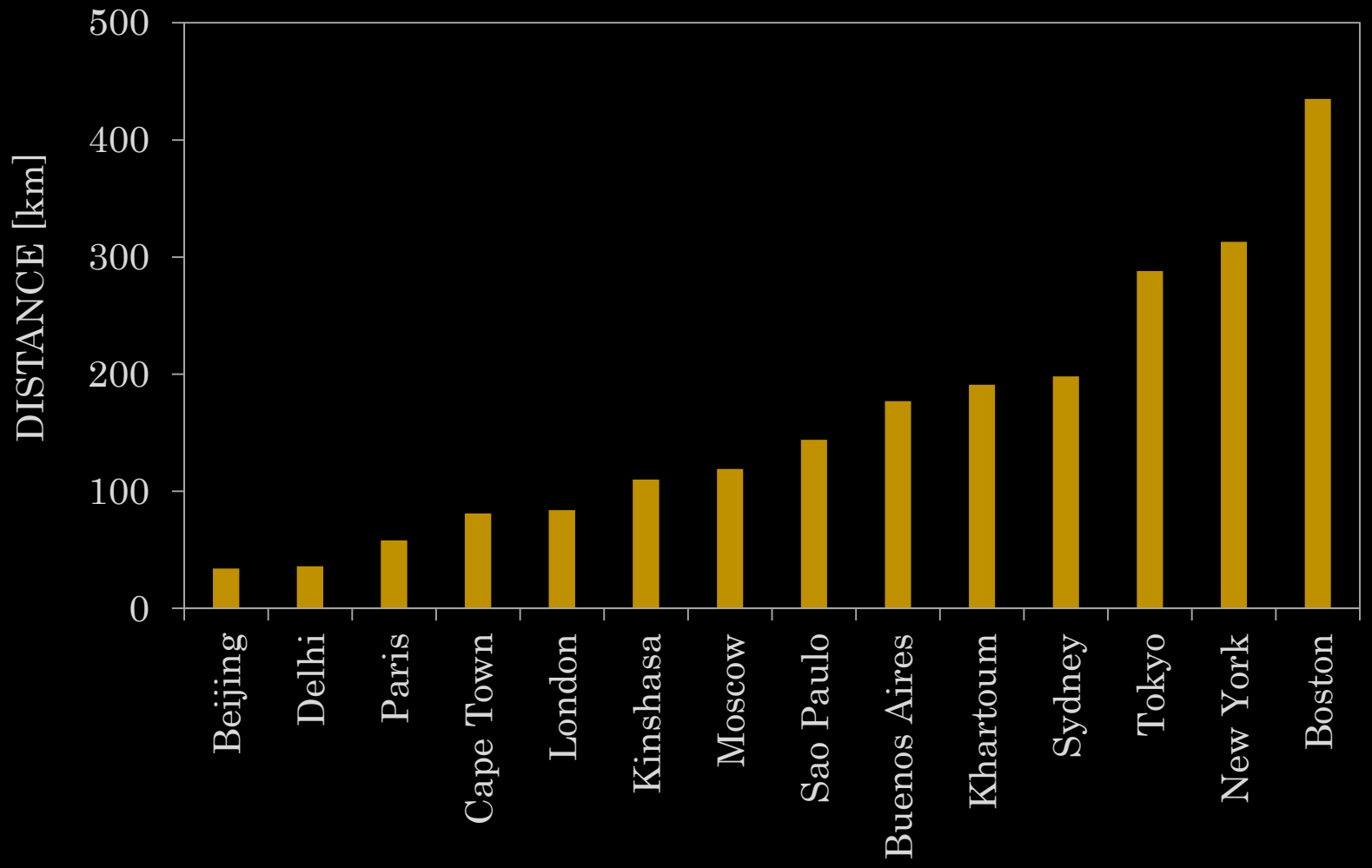



Vinnerås et al. 2006; Rose et al. 2015; Friedler et al. 2013

# Moving urban nutrients to rural farmland = *complex*

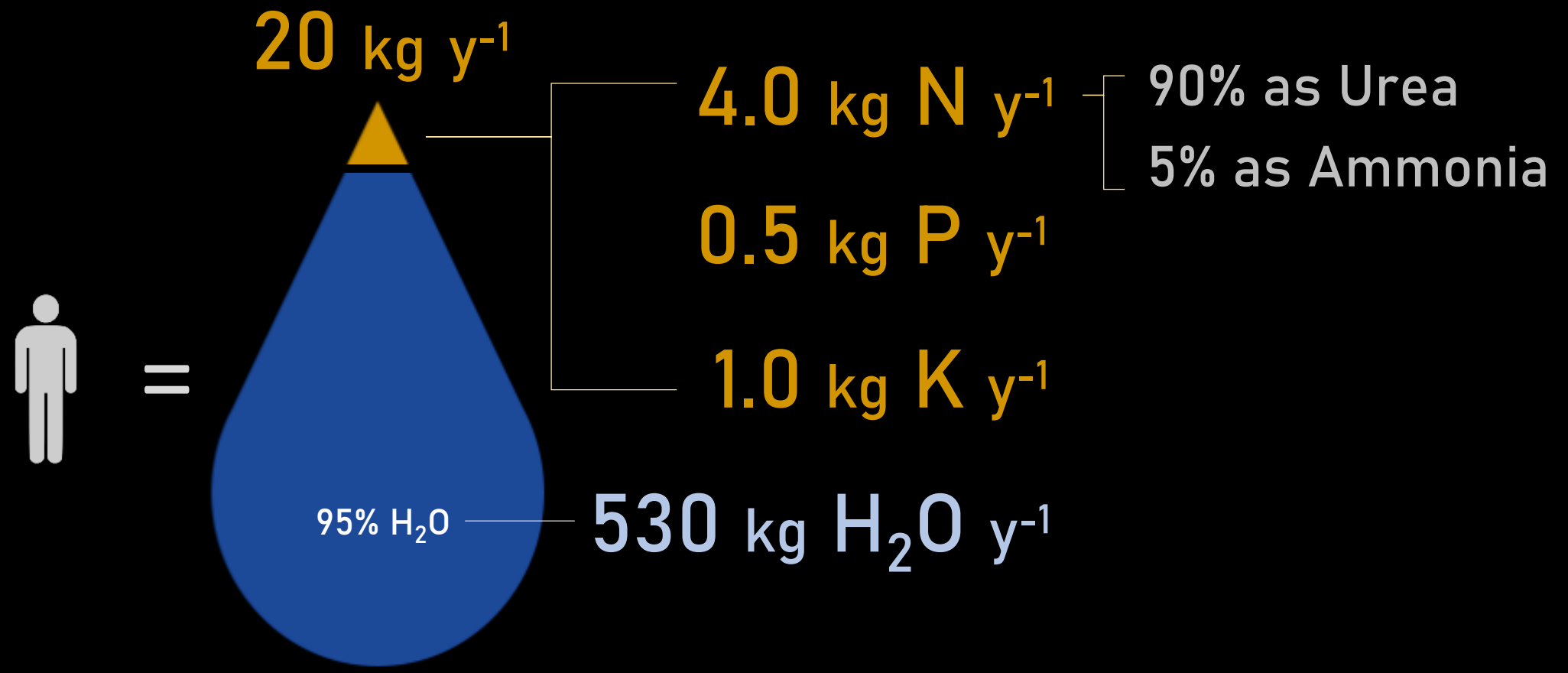


# Distance between CITIES & RURAL Cropland




Trimmer & Guest 2018

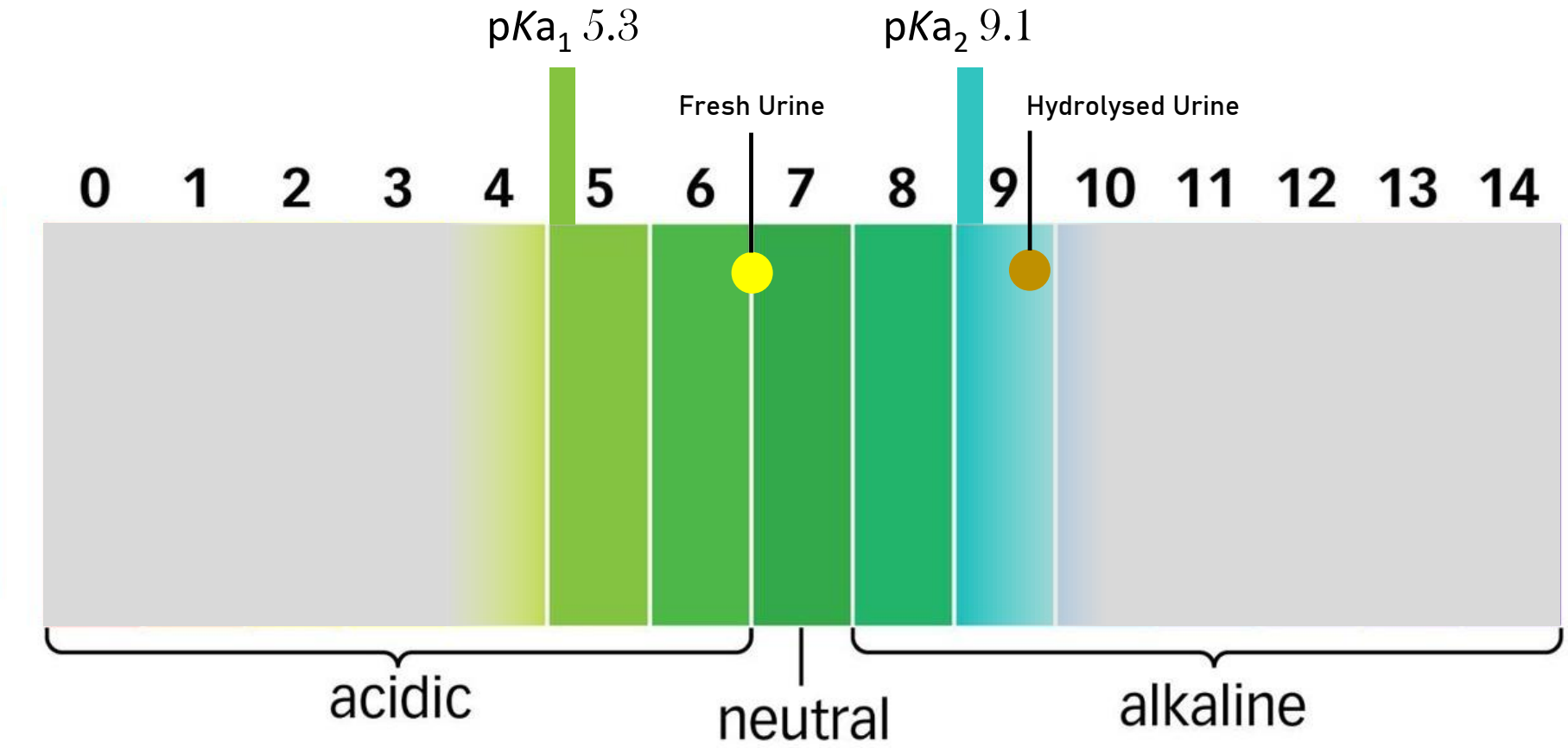
# URINE COMPOSITION




Vinnerås et al. 2006; Rose et al. 2015; Friedler et al. 2013

# STABILIZING URINE

## Inhibiting the enzyme urease

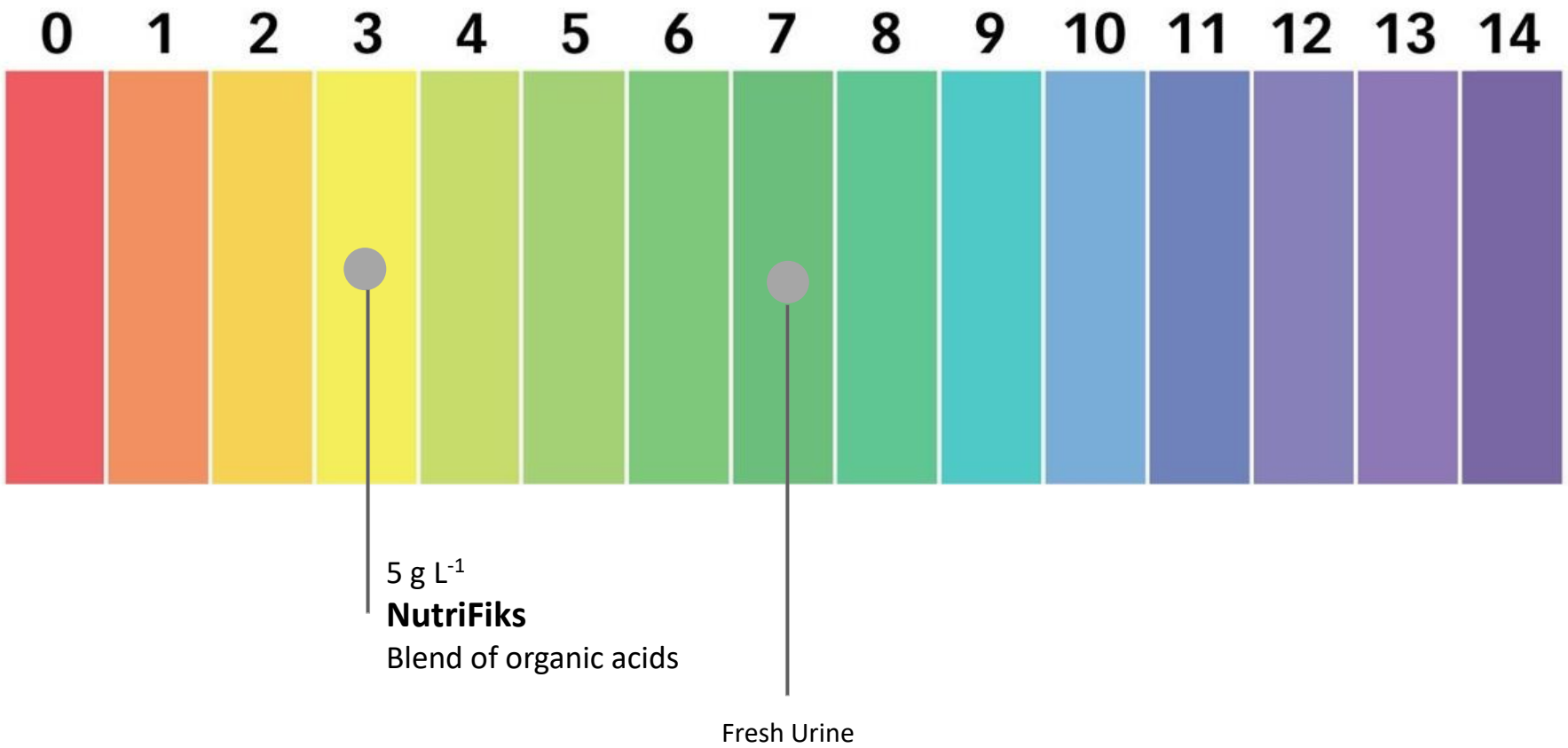



$$CO(NH_2)_2 + H_2O \xrightarrow{urease} H_2NCOOH + NH_3 \xrightarrow{H_2O} H_2CO_3 + 2NH_3$$

Benini et al. 1999; Krajewska and Ciurli 2005; Krajewska, 2009; Geinzer 2017

# STABILIZING URINE

Acidifying urine with **NutriFiks** to inhibit urease

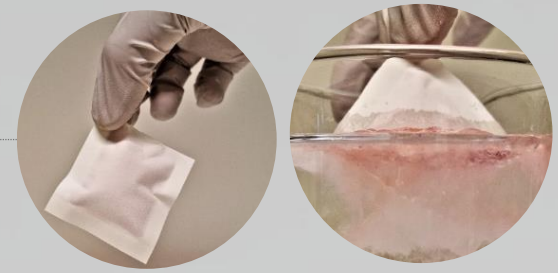



**Chemical Cost = N$ 100 person$^{-1}$ y$^{-1}$**

# How to collect and stabilize nutrients in urine?

This toilet diverts and collects urine separately from rest of the wastewater

Manufactured by LAUFEN, Switzerland

Water-soluble pouches with NutriFiks for stabilising human urine

Dehydrated Urine
Or “Granurin”


## **GranUrin**, *a complete fertiliser*

15-20% Nitrogen
1-3% Phosphorus
4-6% Potassium
15-20% Carbon
1-2% Sulphur
+ Micronutrients

**GranUrin**

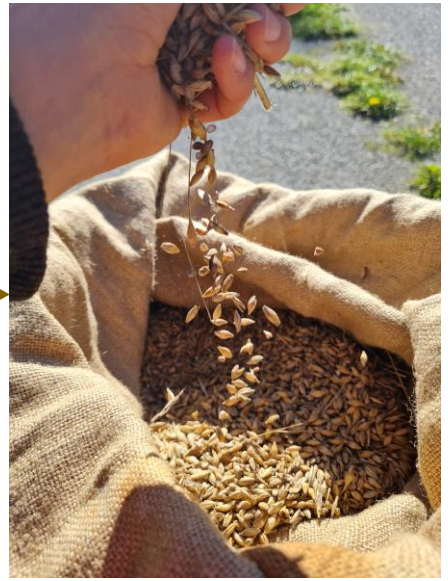
*a solid fertilizer for a reason….*

# **GranUrin** field trials on Gotland, Sweden

We collaborate with Swedish farmers to grow barley and a brewery to produce beer

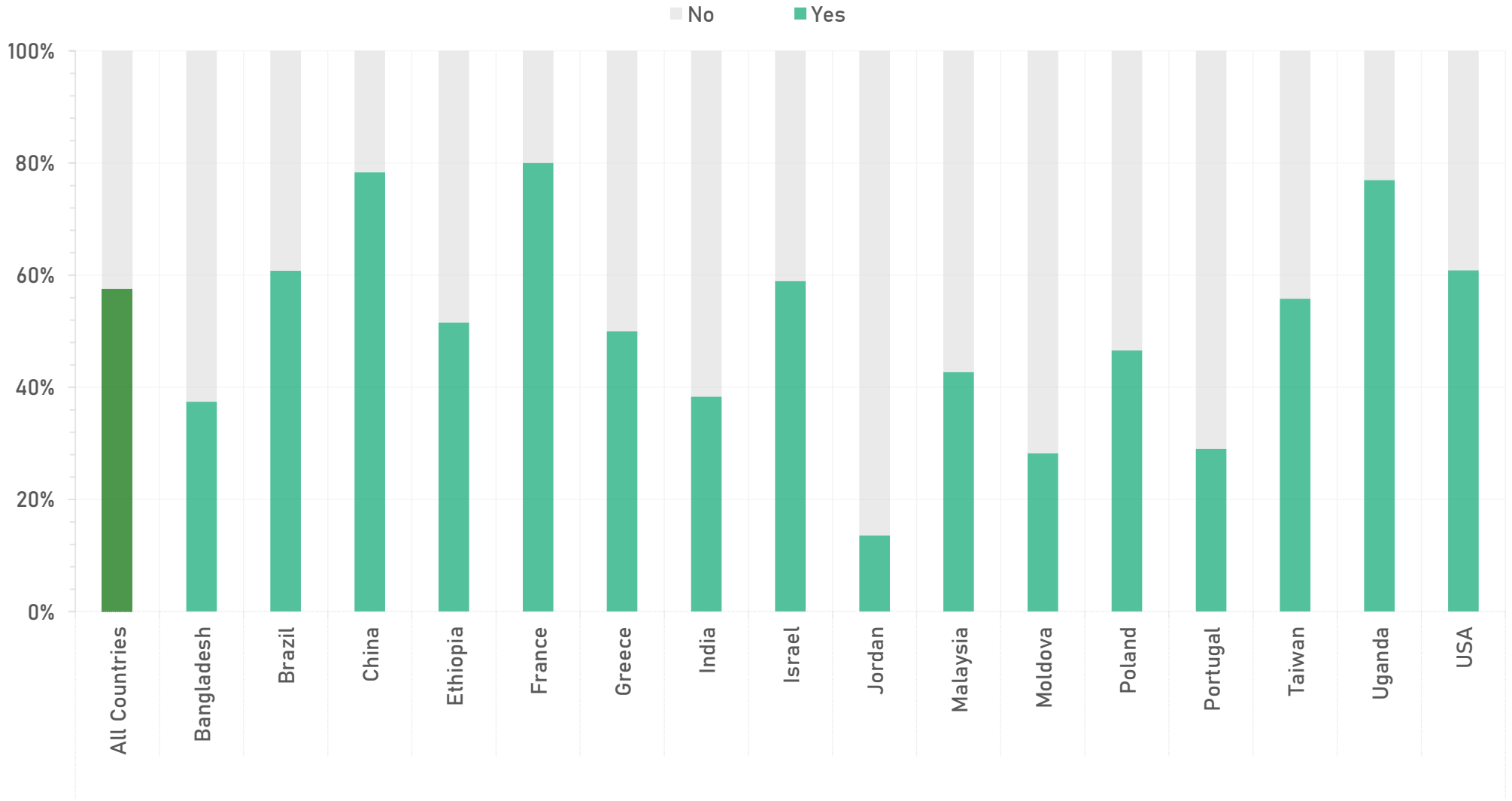
| Fertiliser Treatment | N-P-K Content (%) | Mass fertilizer applied (kg/ha) | Barley Harvest (kg/ha) |
|---|---|---|---|
| GranUrin | 15-2-4 | 567 | 6 500 |
| NKP fertilizer | 24-4-5 | 370 | 6 500 |
| Fresh urine | 0,6-0,07-0,2 | 14 167 | 5 500 |
| Control | 0-0-0 | 0 | 500 |

GOTLANDS + BRYGGERI
VISBY
S:T HANSG
1995



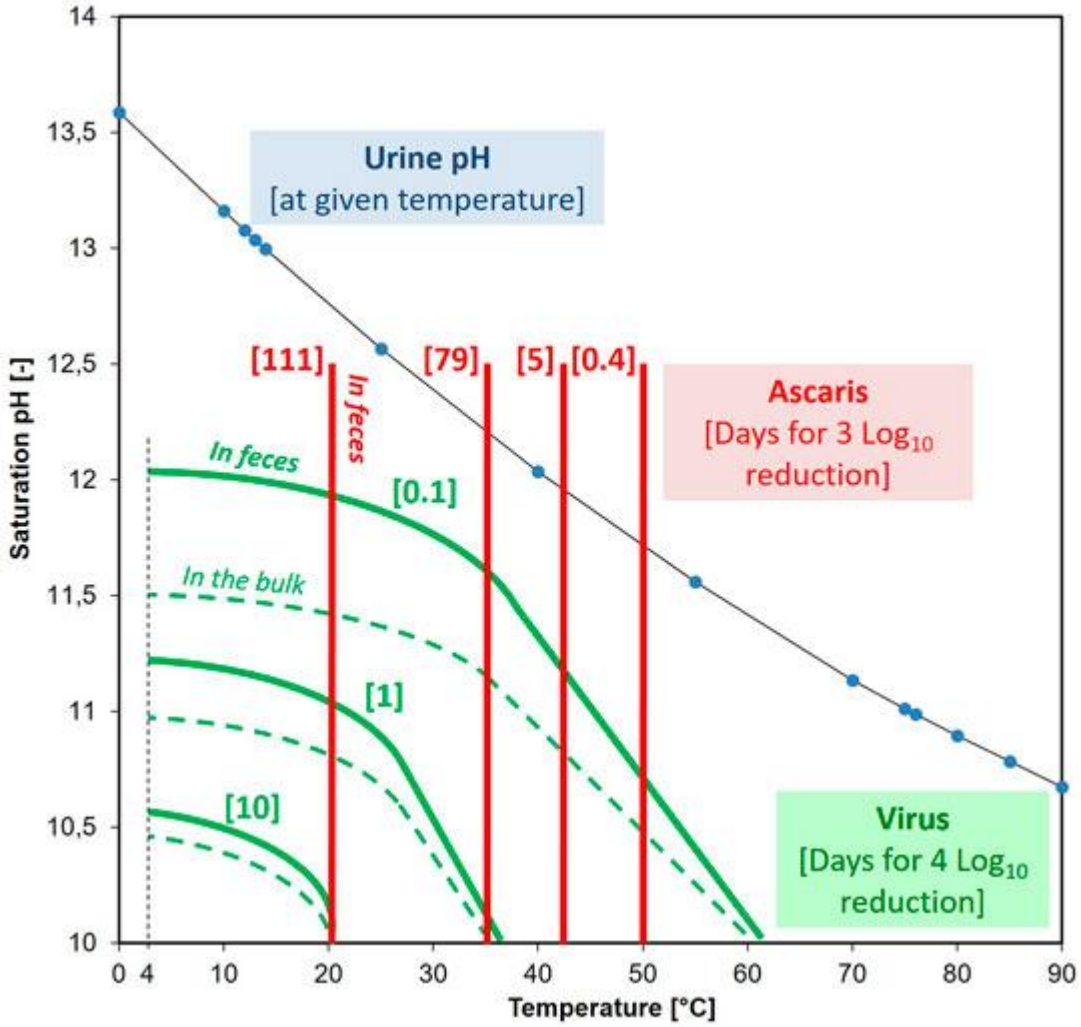
# Will people accept urine recycling?

Willingness to consume food grown with urine-based fertilisers




Simha and Barton et al. 2021. Science of the Total Environment

# Is **Granurin** a safe fertiliser?




ELSEVIER

Water Research

Volume 144, 1 November 2018, Pages 474-481

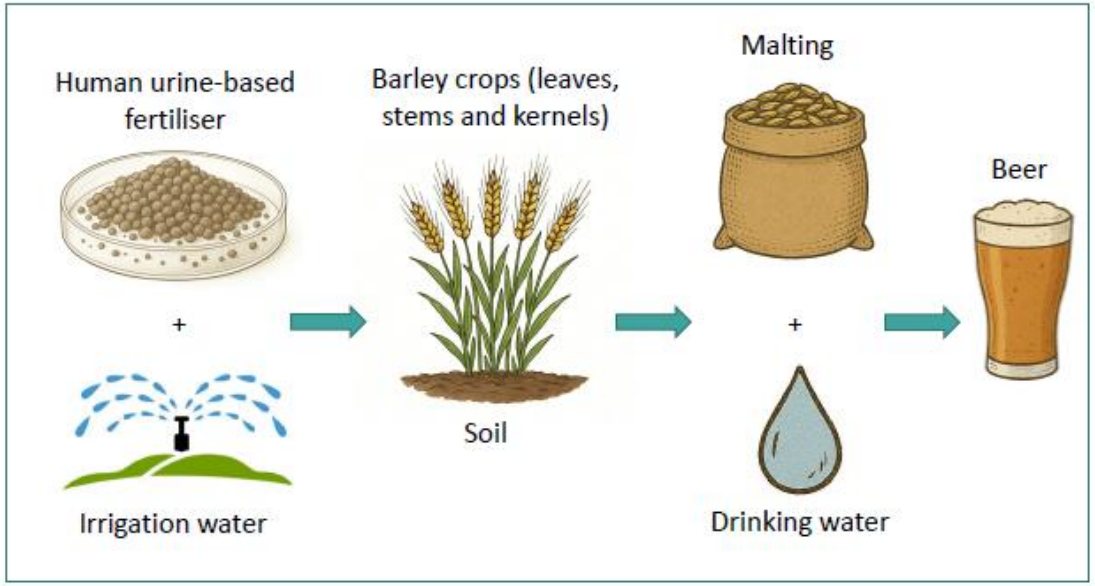
## Hygiene aspect of treating human urine by alkaline dehydration

Jenna Senecal, Annika Nordin, Prithvi Simha, Björn Vinnerås

**Granurin** meets wastewater recycling guidelines of:

US Environmental Protection Agency (USEPA)
World Health Organisation (WHO)
EU Fertiliser Product Regulations (in 2026)

# Fate of 40 pharmaceuticals in circular beer production using barley fertilised with Granurin


Real urine collected from public urinals in Sweden – representative sampling
7 out of 40 pharmaceuticals detected in Granurin, BUT in nano-gram per gram levels – it is really, really low
**NO pharmaceuticals detected in barley, malted barley, or beer**

# How can we recycle urine in practice?

The Swedish Experience

**How can we recycle urine in practice?**

The Swedish Experience

*Technified approaches*

*A urine-separating and dehydrating toilet installed at offices of VA Syd in Malmö, Sweden*
*In continuous operation since 2021*

*A urine-separating and dehydrating toilet installed at the offices of VA Syd in Malmö, Sweden*
*In continuous operation since 2021*

# Recycling urine – *in practice*

Retrofitting public toilets/urinals
Scalable/Modular

*Installed at SLU, Uppsala*

# Recycling urine – *in practice*

Mobile and Multi-tenants

*We collect urine from festivals (Valborg) and sporting arenas*

# Treating urine using waste heat from industries


# Recycling urine in Sweden

*The Studenternas Football Stadium in Uppsala*

# Urine collection, stabilization and vacuum sewers at the Studenternas Football Stadium in Uppsala

# Urine collection, stabilization and vacuum sewers at the Studenternas Football Stadium in Uppsala

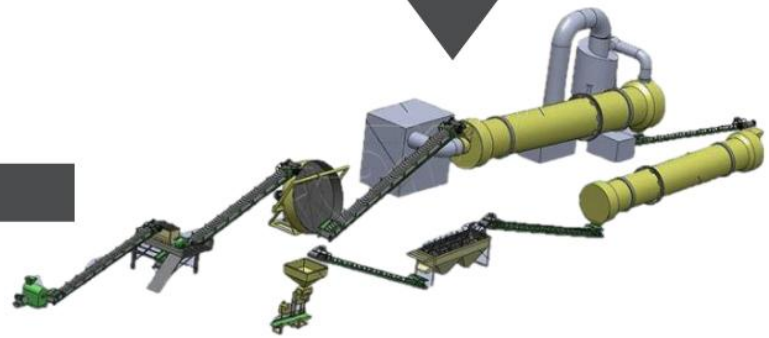
# Overall Recycling Process

**Stabilizer**
(added to the toilet or urinal's urine collection tank)

**Urine diverting toilet or urinal**

**Stabilized urine**

**Urine Drying System**
(concentrates the urine x 25)

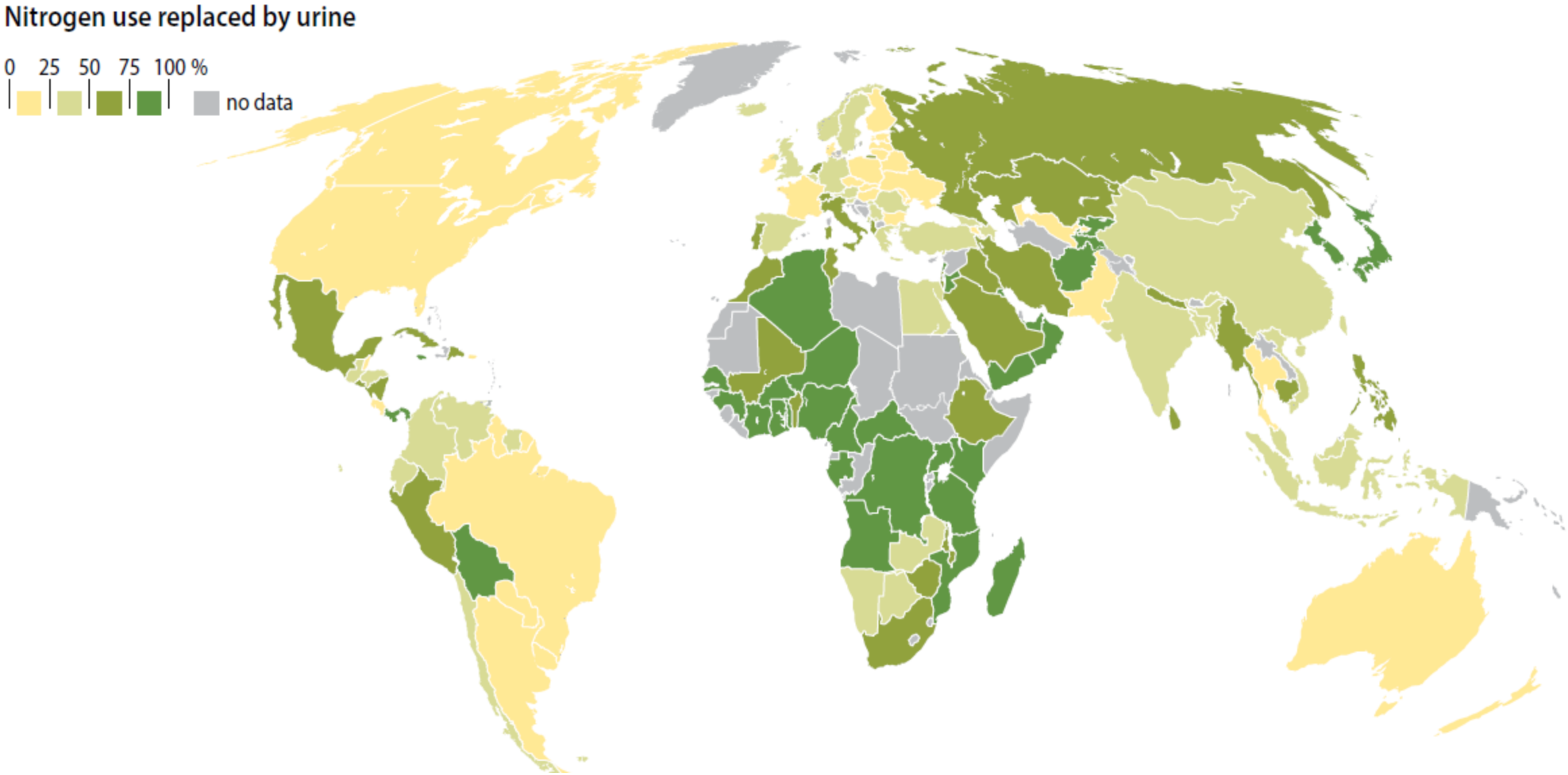


**Production Facility**
(Stabilizer blending and packaging, In-house manufacturing; Fertiliser factory)

**Dry Fertilizer Pellets**
(achieved NPK = 15-2-4)

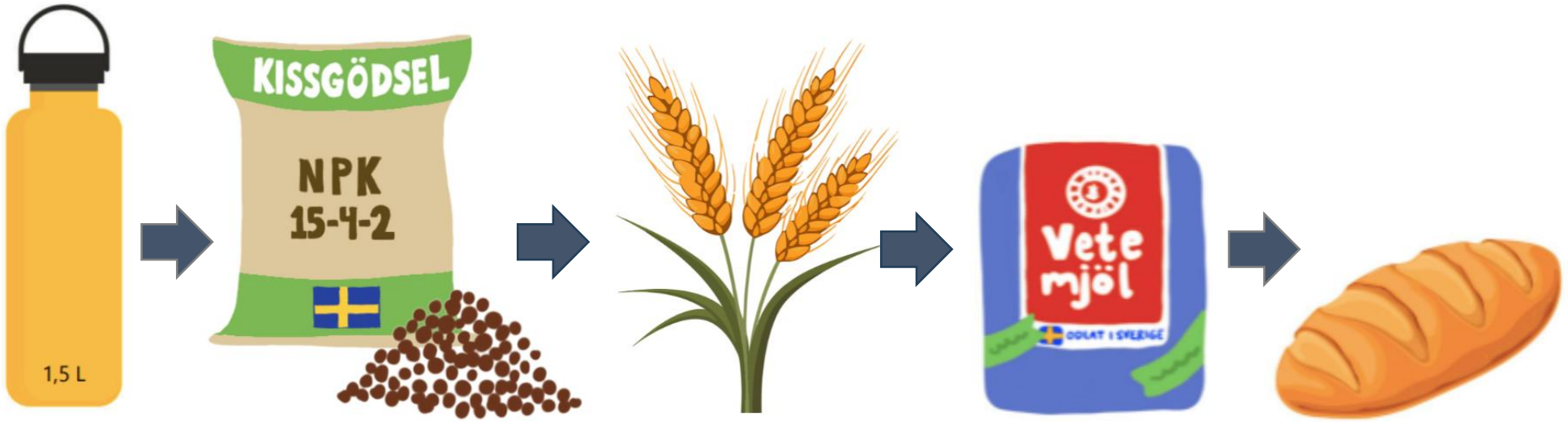
**Applied on fields**

# The potential for human urine-derived nutrients to meet global nitrogen and phosphorus demand in agriculture

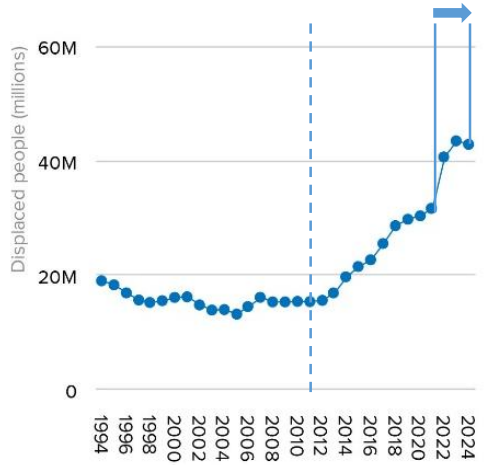



UNEP Rapid Response Assessment Report (2023)
Data Source: https://osf.io/4akmf

# Take away…

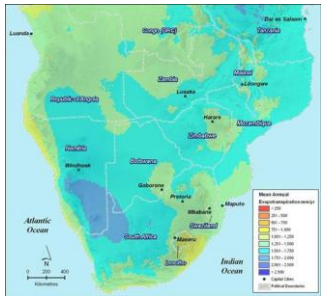


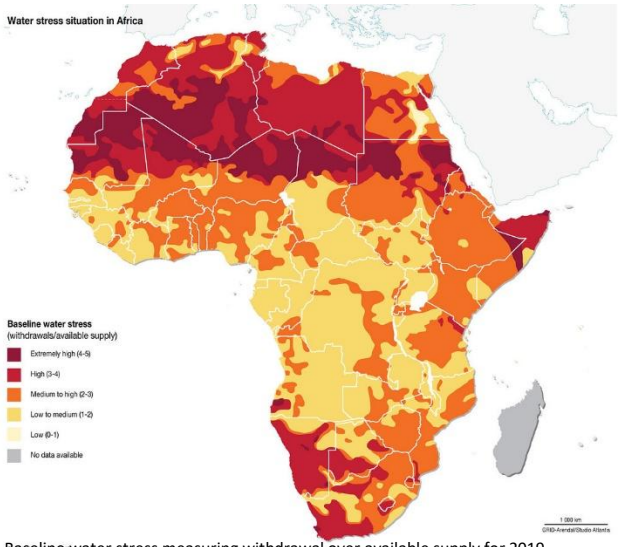

*1 person's daily pee* = *Enough nutrients to grow the wheat for a whole loaf of bread*



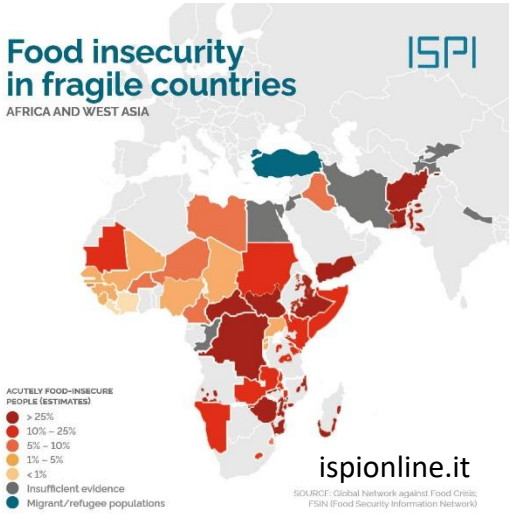

Source: UNHCR Global Trends 2024, 12 June 2025.

The number of refugees and forcibly displaced people has tripled from 40 million in 2011, to 123.2 million in 2024.

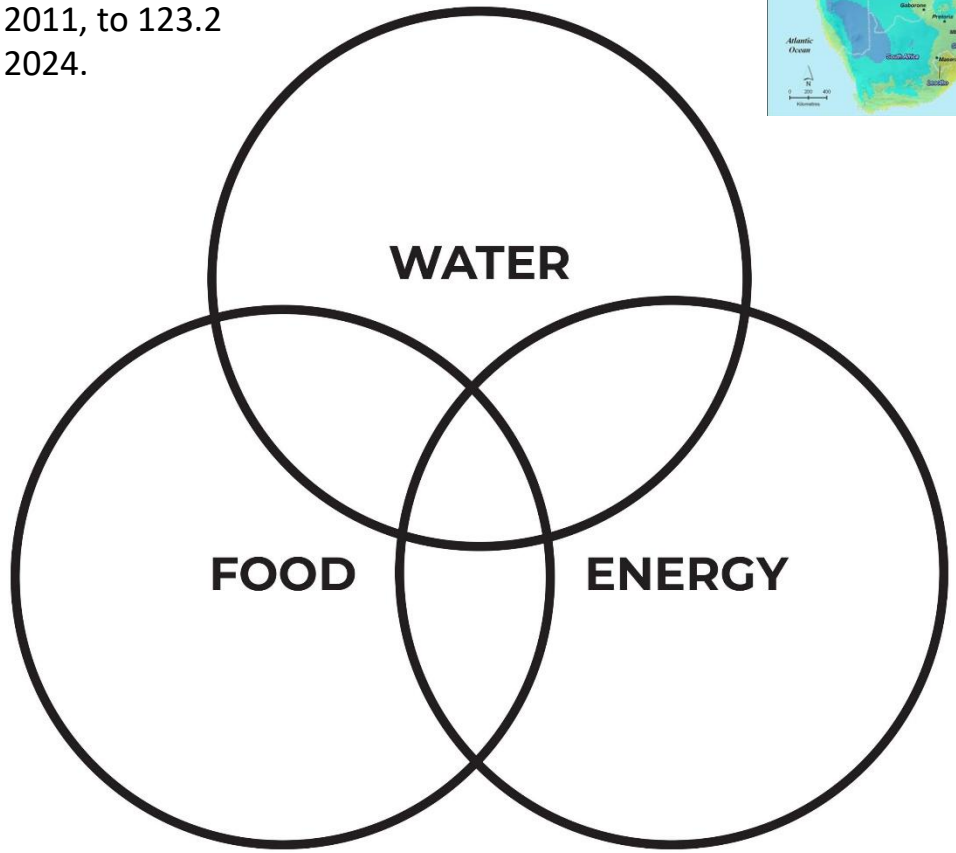


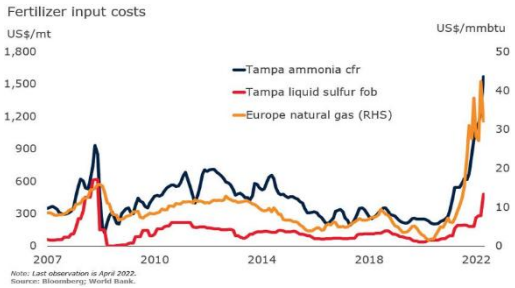



~~Baseline~~ water stress measuring withdrawal over available supply for 2019 – map produced in 2020 by *www.grida.*no from UNEP data




ispionline.it




Ammonia manufacturing today contributes **between 1 and 2% of worldwide carbon dioxide emissions _** climate.mit.edu

72% of ammonia is produced using steam reforming of **natural gas,** a non-renewable resource_ iipinetwork.org

About **80% of ammonia produced is used as fertiliser** - applied directly or converted to solid fertilisers (e.g. **urea**, ammonia nitrate) _ iipinetwork.org

**Globally:**

Over the next 25 years, the amount of energy used in the water sector will **more than double.**

The energy sector is set to increase energy-related water consumption by nearly **60%** between 2014 and 2040.

**International Energy Agency**

iea.org

The synthesis of ammonia through the **Haber Bosch** process is the source of nearly all nitrogen fertilisers.

- **200bar & 400-450 °C**

Ammonia is the second-most commonly produced chemical in the world _ climate.mit.edu

# Who should we target?

**Globally:**
55% of the world's population lives in urban areas

**1.1 billion people live in slums _ UN**

85% concentrated in three regions:
- Central and Southern Asia (359 million)
- Eastern and South-Eastern Asia (306 million)
- Sub-Saharan Africa (230 million).

**Urbanisation** is projected to rise to **70%** and an additional 2 billion living in **slums by 2050**, mostly in the Global South _ UN

Water consumption is projected to increase by 50–80% over the next three decades (Flörke, *et al.*, 2018, Garrick, *et al.*, *2019*, He, *et al.*, 2021).

Riverbeds in most informal settlements are dumping zones. This waterway in Peter Nanyemba, Windhoek, is polluted by the lack of sanitation, refuse, and stormwater that collects and is made worse during the rainy season

Source: Namibia Housing Action Group

# Who should we target?

**Globally:**

**257 million** people experience **acute food insecurity**, explicitly linked to drought

608 million farms

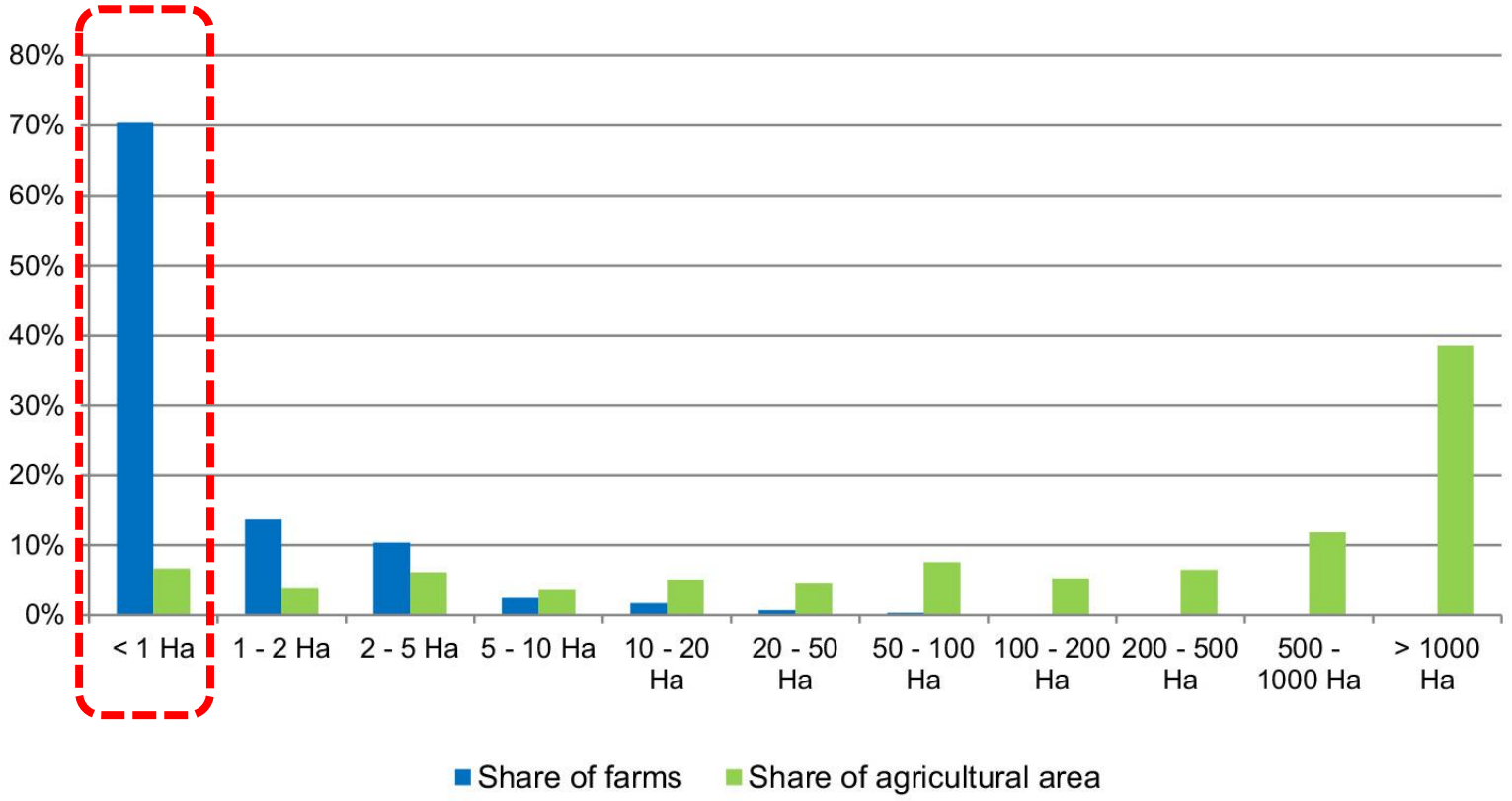
**90%<** family owned - producing roughly **80% of the world's food** in value terms, on about **70–80**% of available farmland (Lowder *et al.*, 2021).

Smallholders (<2 ha)

- 12% of agricultural land, but produce 35% of the world's food
- **84% of all farms worldwide (<** 1 ha = 70%)

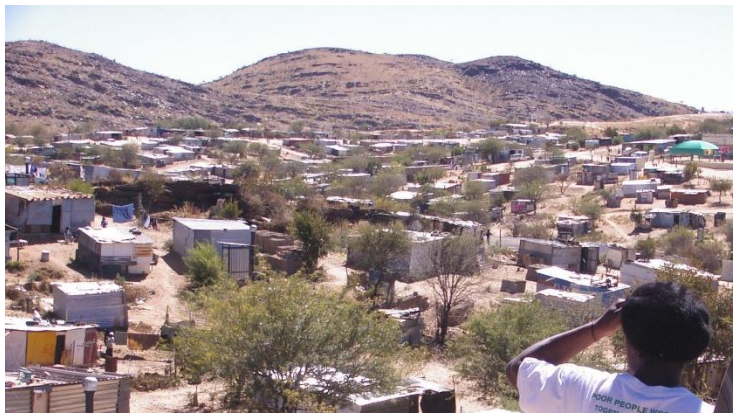
(Lowder et al., 2021).

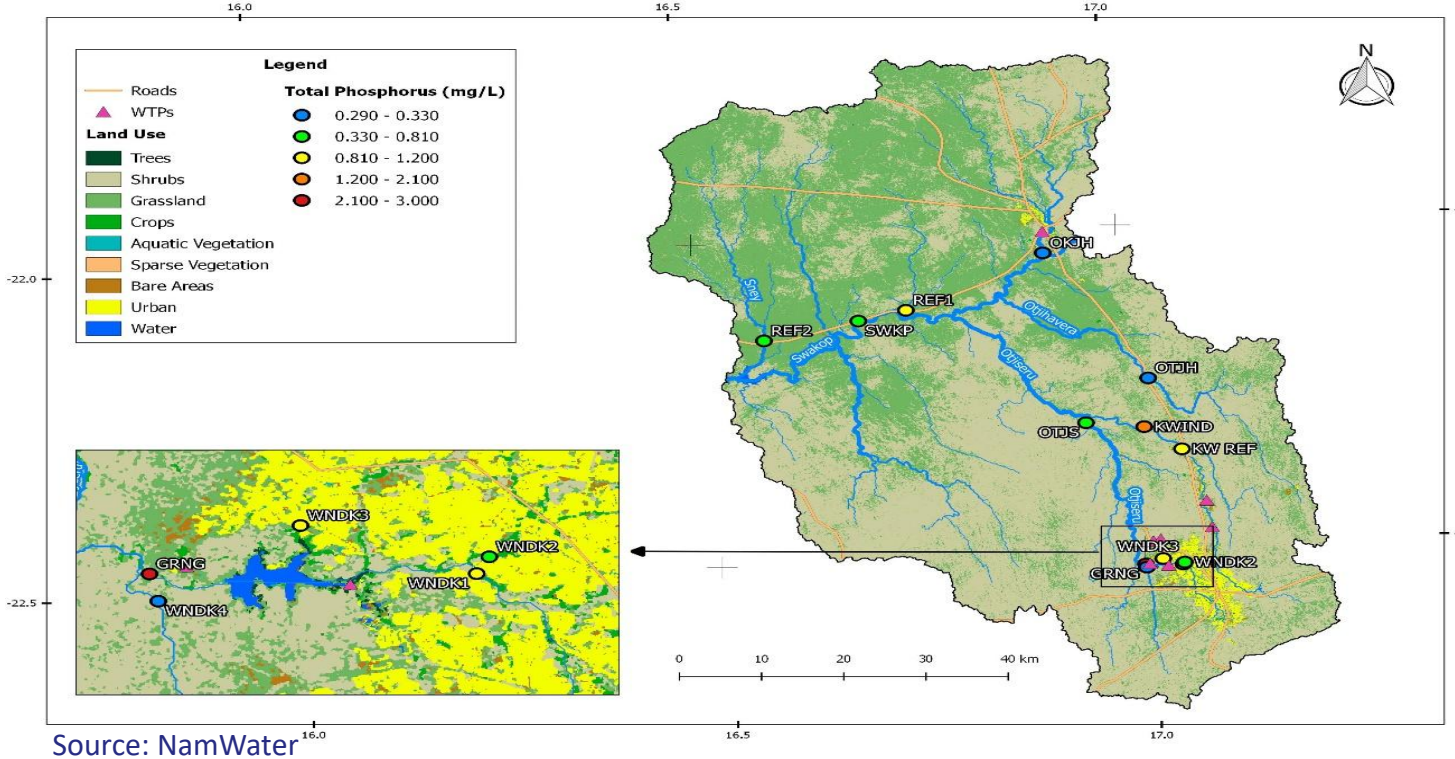
The International Organisation for Migration's 12th report estimates that **218.6 million people are internally displaced due to weather-related disasters.** It singled out **drought-displaced populations.**

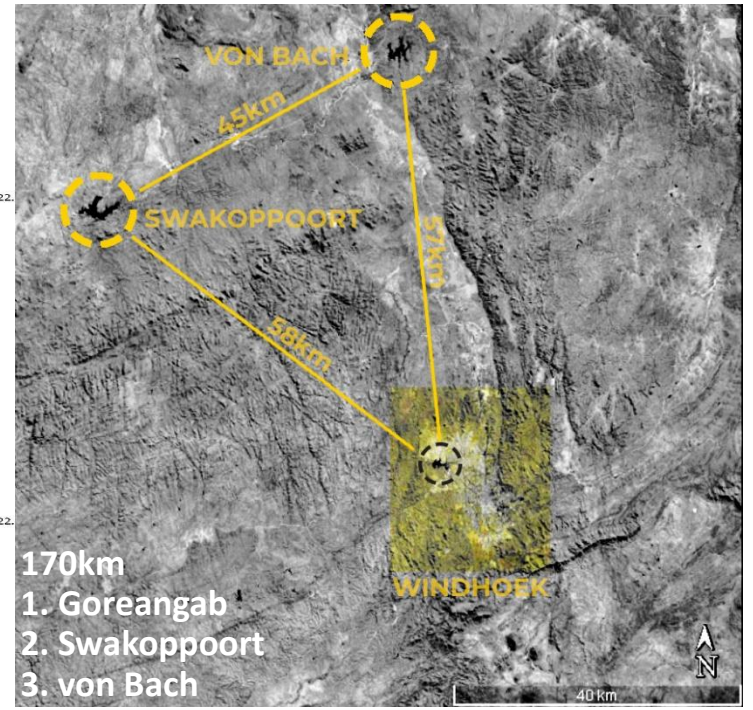


# UPPER SWAKOP CATCHMENT AREA

Median Total P concentrations – December 2019 to March 2020




Source: NamWater

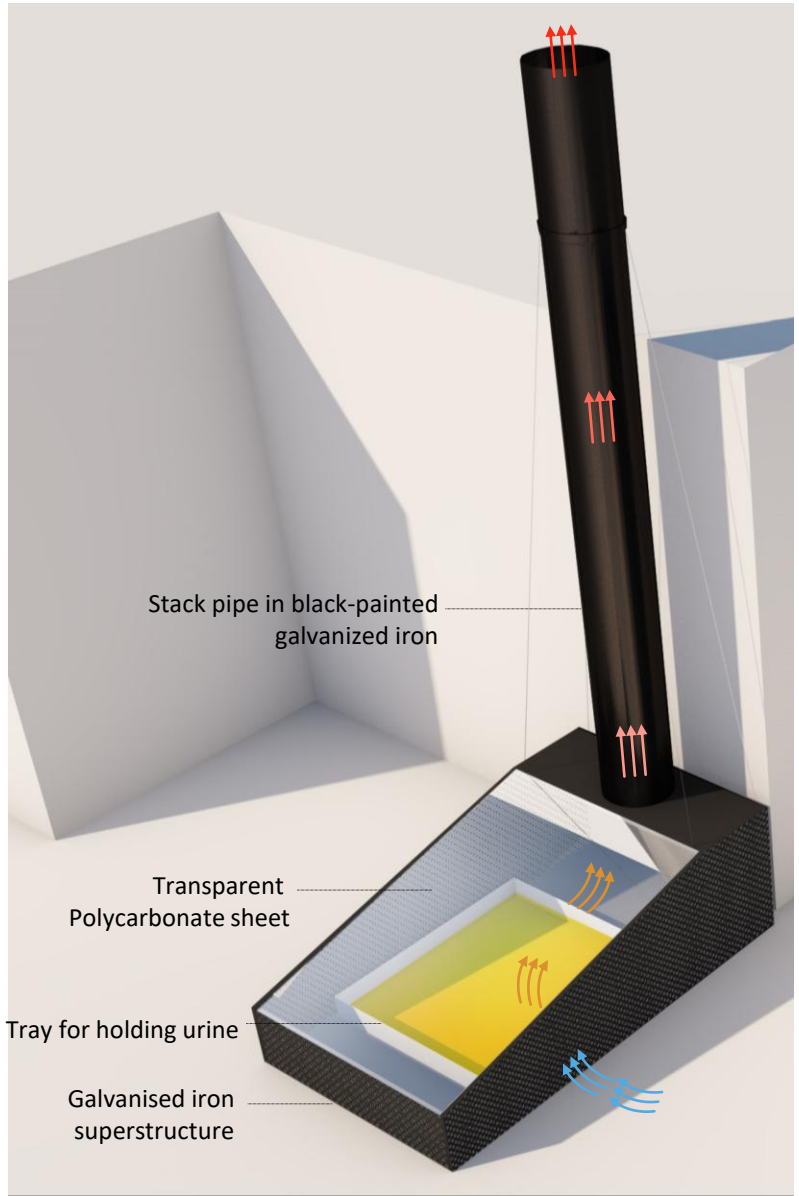
(Linus Kapulwa & Fillemon Aupokolo - Division Represented: Applied Scientific Services)

# The **AirCloset**

## Technical evaluations

| Timestamp | Value |
|---|---|
| April 22, 2024 21:10:04 | 5.85 |
| April 22, 2024 21:05:04 | 5.85 |
| April 22, 2024 21:00:06 | 5.85 |
| April 22, 2024 20:55:06 | 5.85 |
| April 22, 2024 20:50:04 | 5.9 |
| April 22, 2024 20:45:03 | 5.9 |
| April 22, 2024 20:40:04 | 5.9 |
| April 22, 2024 20:35:04 | 5.9 |
| April 22, 2024 20:30:03 | 5.9 |
| April 22, 2024 20:25:04 | 5.9 |
| April 22, 2024 20:20:04 | 5.95 |
| April 22, 2024 20:15:03 | 5.9 |
| April 22, 2024 20:10:04 | 5.95 |

Scale – Rasp pi (local storage) - LAN - Sweden Server (cloud storage) – Webpage





**Final setup config**

Facing: North

Inclination: 23 deg, latitude

Whirlybird: Suction and odor management

Flap for air inlet: Modulating air flow

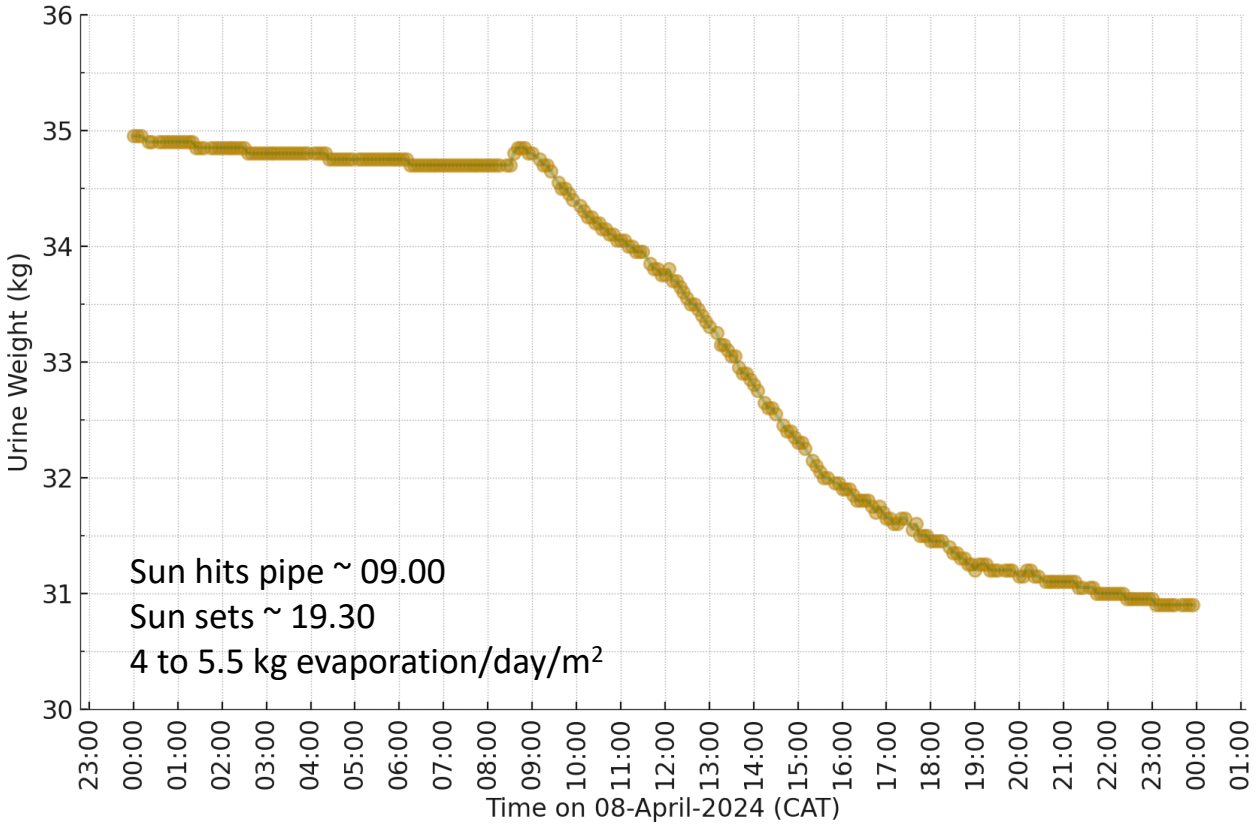
3 M stack pipe: real-life settings

Side vents: For interconnection

Surface Area: 1 $m^2$, expandable to 1.5 $m^2$

Volume Capacity: 100 L, expandable to 300 L

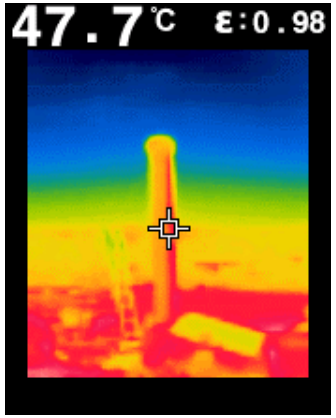
*Works with acidified urine*



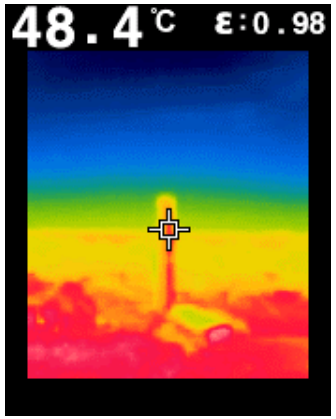


## FLIR Images

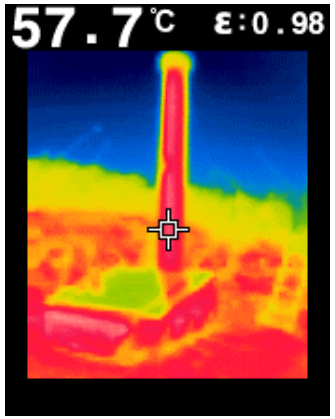
Pictures taken ~ midday



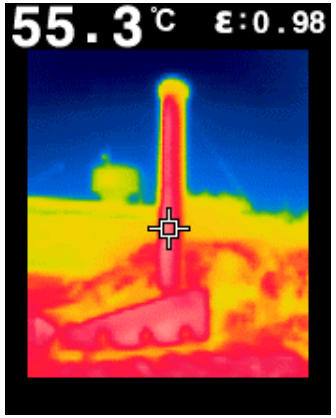
East



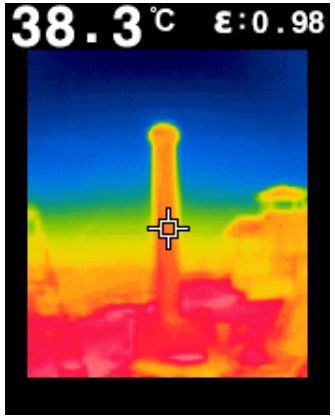
North-east



North-west



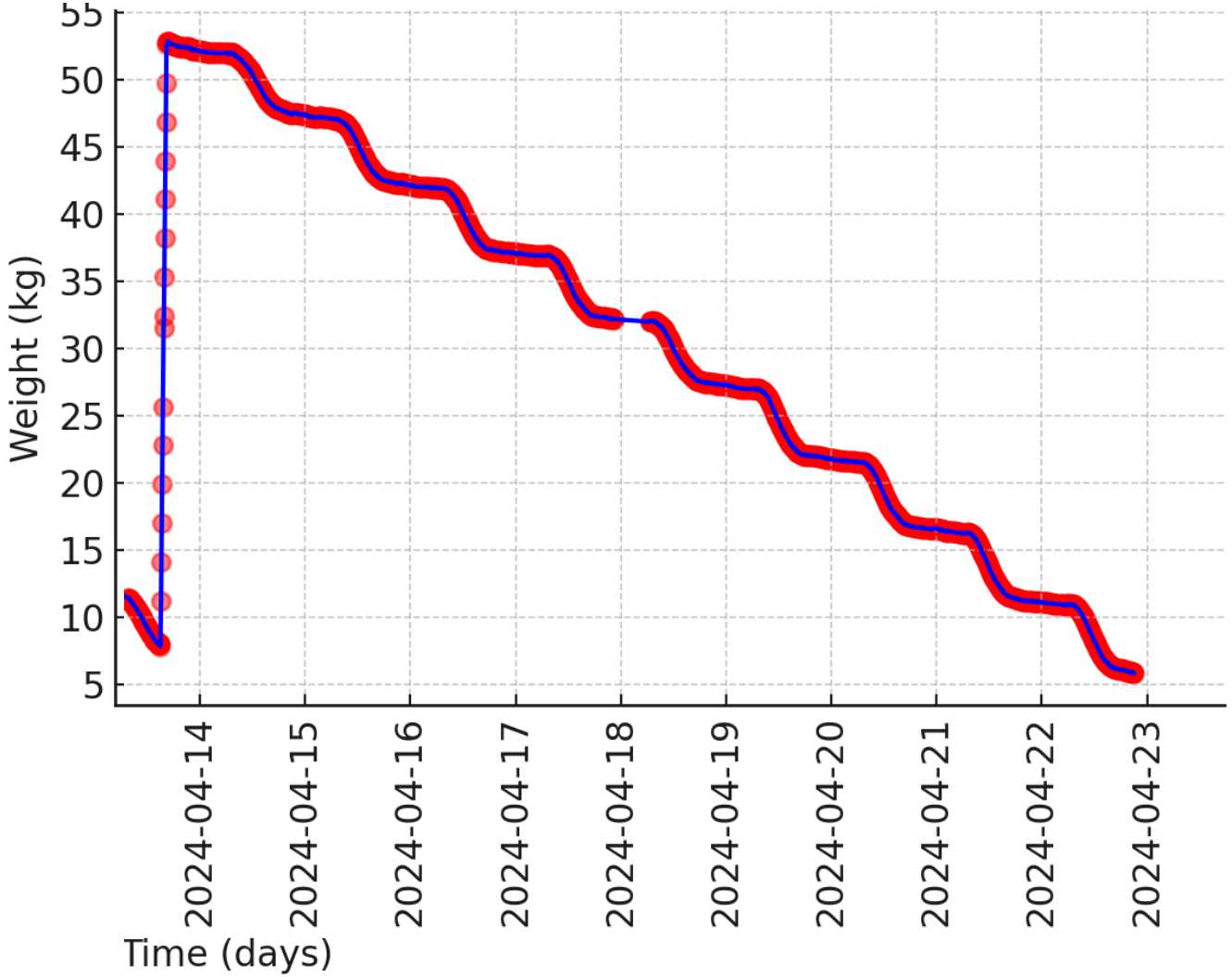
West



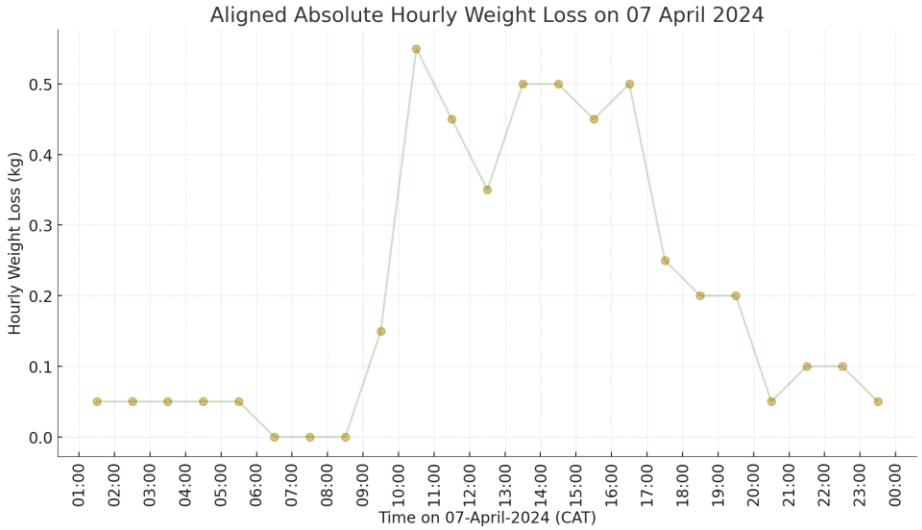
South

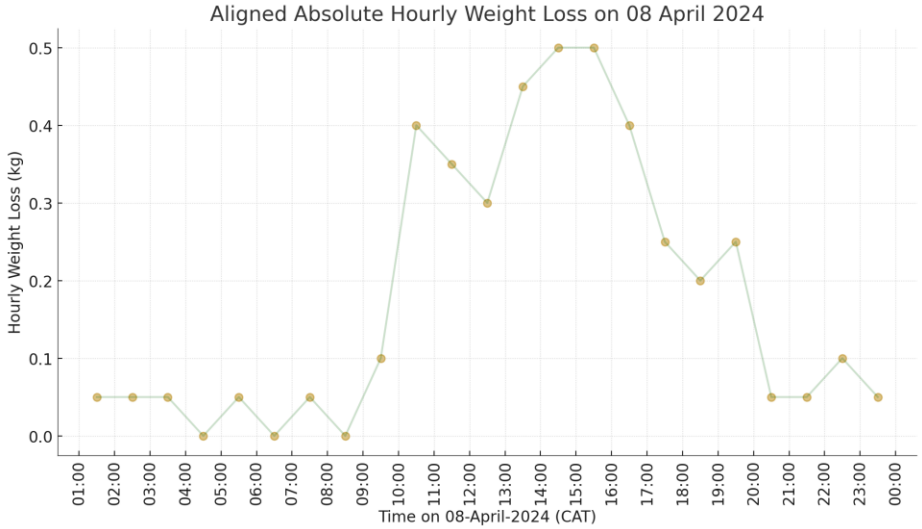
Ambient, building

# 50kg batch over 10-day cycles




# Hourly weight loss



# The **AirCloset**

## Technical evaluations

### **Testing variables**

Side-vents

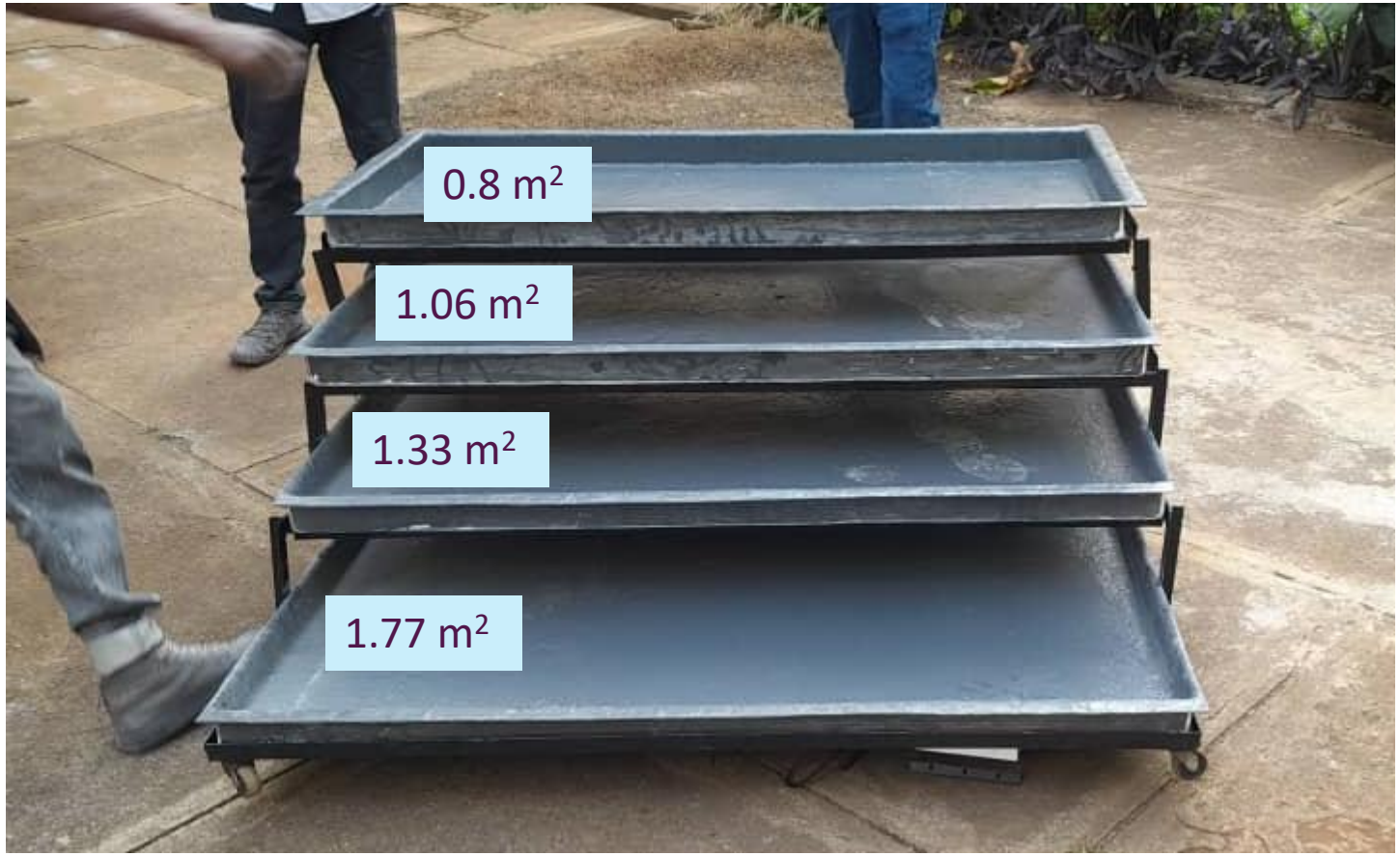
Vent-pipe diameters

Air-inlet

# The **AirCloset**

## Technical evaluations

**Testing variables:** Multi-tray system




FoodSecUR Project, Ethiopia

# The **AirCloset** Namibia National Urban Dialogue



# The **AirCloset** Namibia
# Field Trials: Replication






# The **AirCloset** Namibia Field Trials: Replication



The **AirCloset**

Field Trials: **Peter Nanyemba**

Identifying collection points

The **AirCloset**

Field Trials: **Peter Nanyemba**

Opportunities

# The **AirCloset**
# Field Trials: **Peter Nanyemba**
# Opportunities

# The **AirCloset**
# Field Trials: **Rehoboth** Opportunities

# The **AirCloset**
# Field Trials: **Rehoboth**

# The **AirCloset**
# Field Trials: **Rehoboth**


# The **AirCloset**

## Field Trials: **Kabila C, Havana**

# The **AirCloset**
# Field Trials: **Kabila C, Havana**


# The **AirCloset**
# Field Trials: **Osire Refugee Camp**

# The **AirCloset**
# Field Trials: **Osire Refugee Camp**



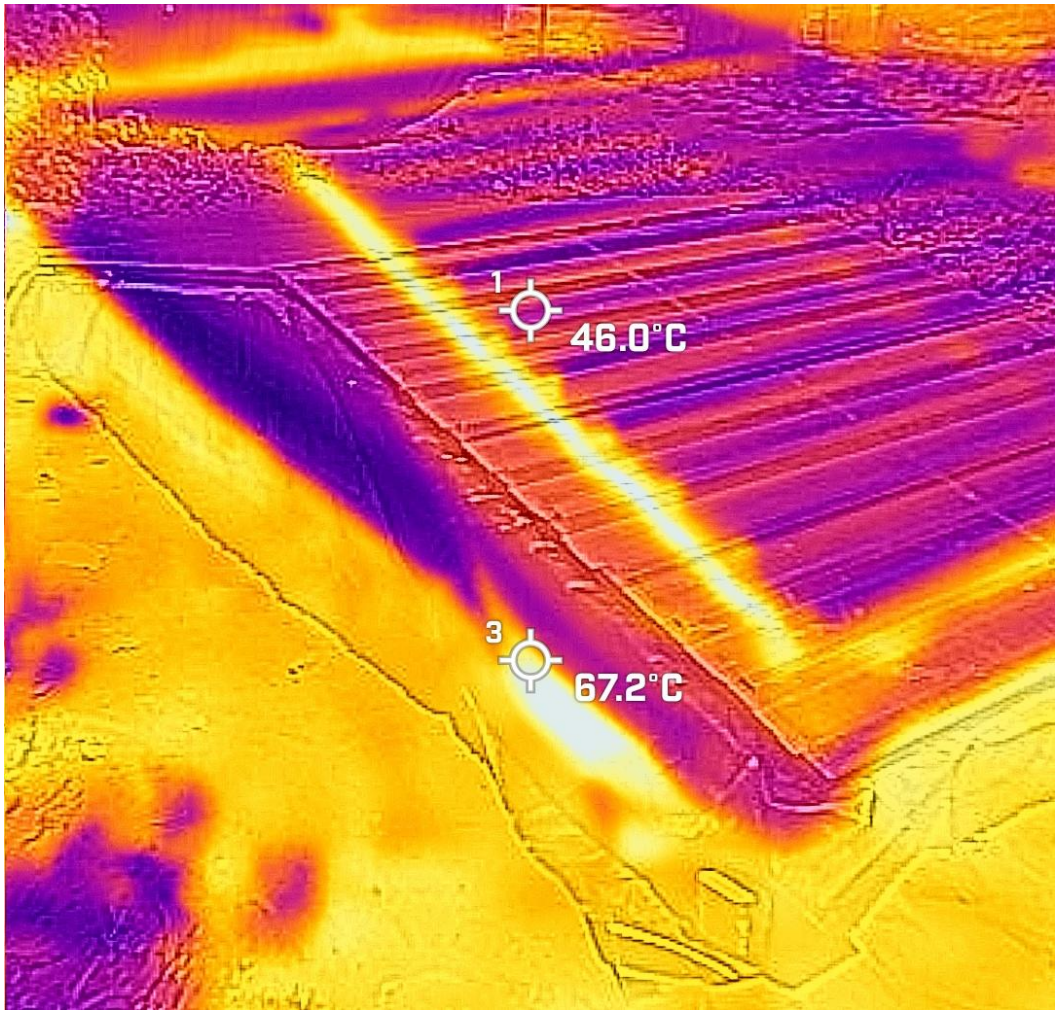


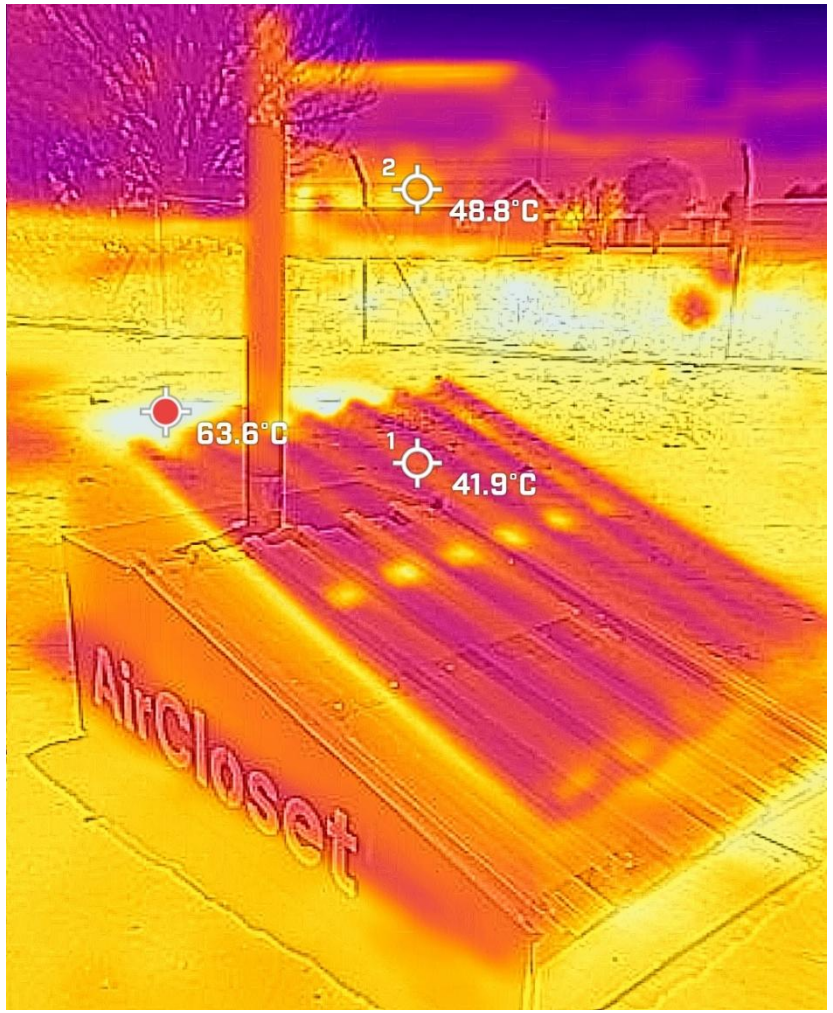




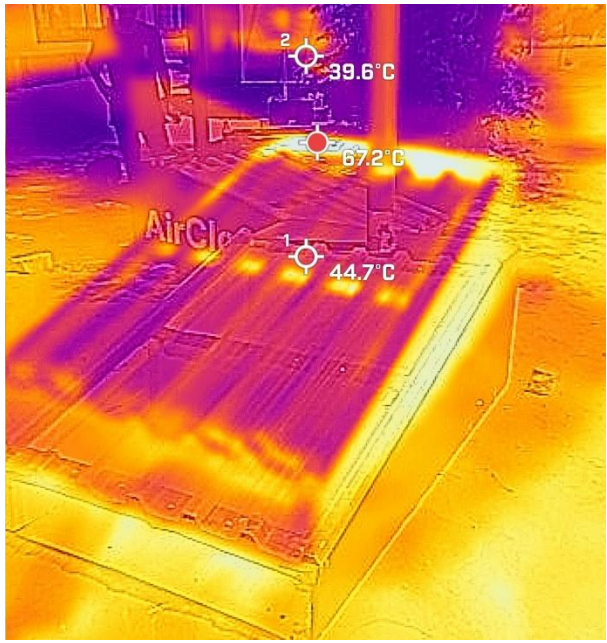
AirCloset


AirCloset


1
46.0°C
3
67.2°C


2
48.8°C
63.6°C
1
41.9°C
AirCloset


1
52.0°C
67.6°C


2
39.6°C
67.2°C
1
44.7°C

## Get in touch with us?

Project Website: https://aircloset.org/

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