The promise of eCooking

Experimental Evidence from Eastern Congo

Randomized Controlled Trial in Goma, DRC

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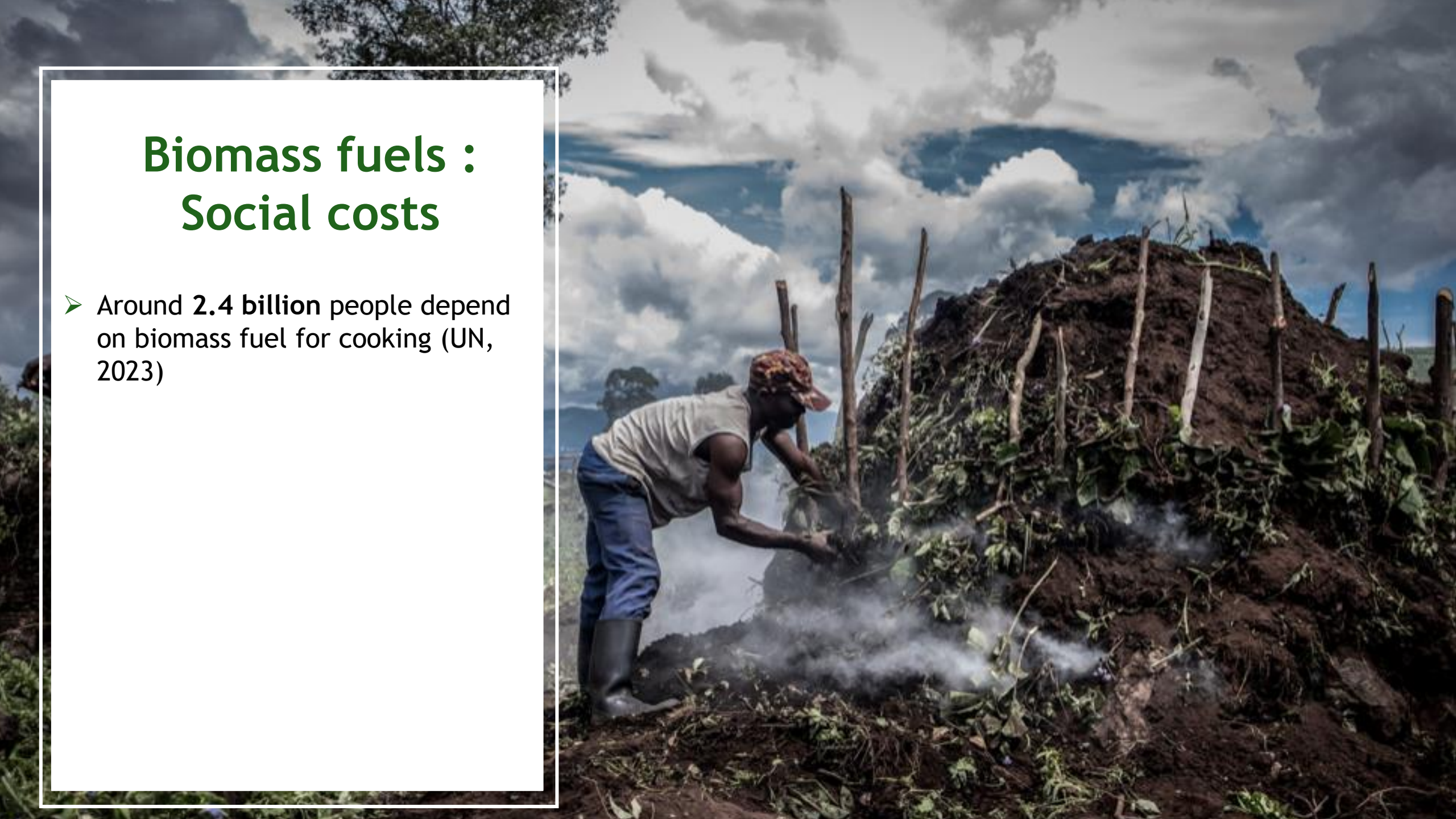
Opening new horizons

PEDL

Biomass fuels : Social costs

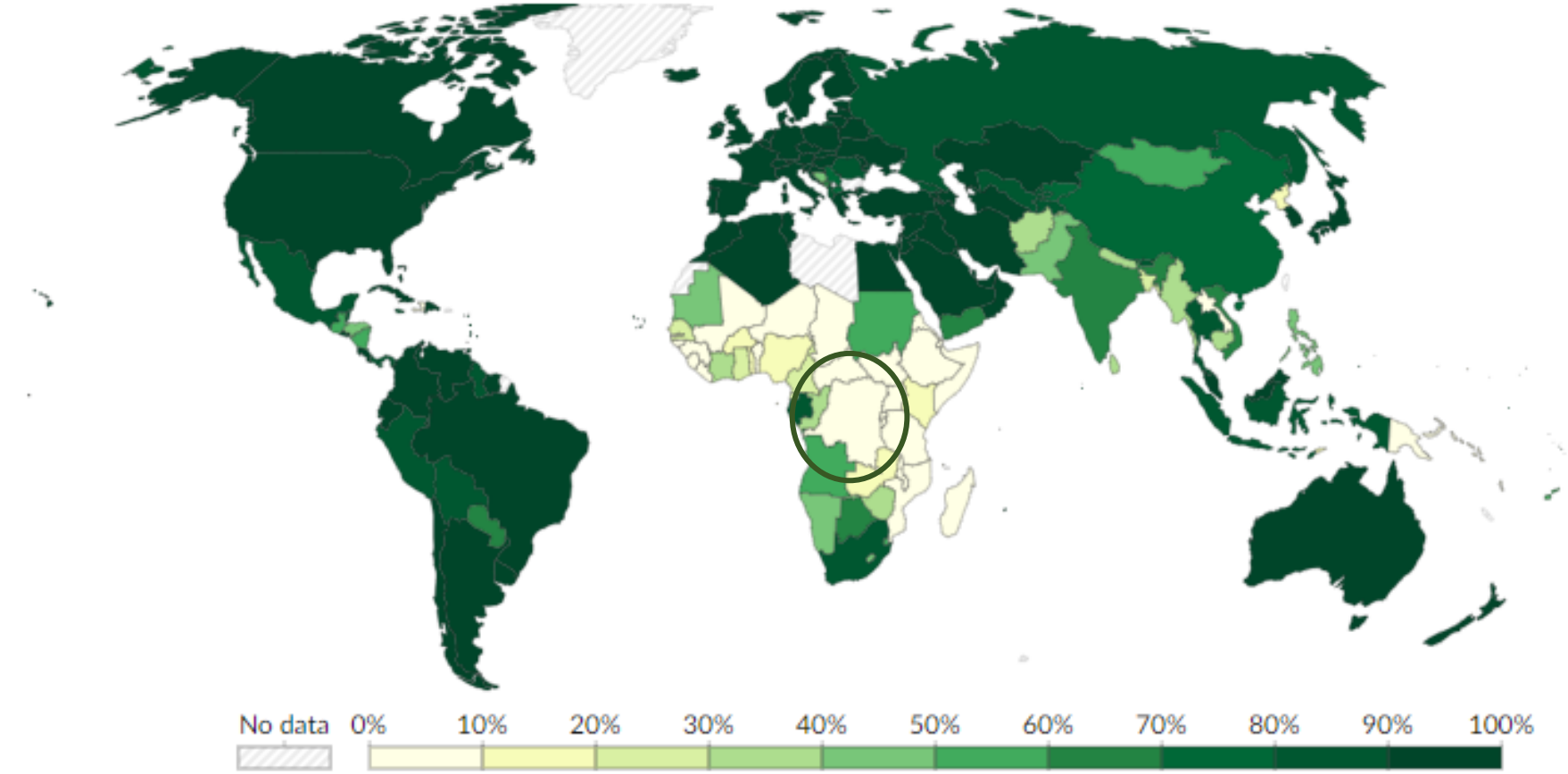
- Around **2.4 billion** people depend on biomass fuel for cooking (UN, 2023)



Share of the population with access to clean fuels for cooking, 2020

Access to clean fuels or technologies such as natural gas, electricity, and clean cookstoves reduce exposure to indoor air pollutants, a leading cause of death in low-income households.

Our World in Data



Data source: WHO, Global Health Observatory (2022) - Learn more about this data

OurWorldInData.org/energy | CC BY

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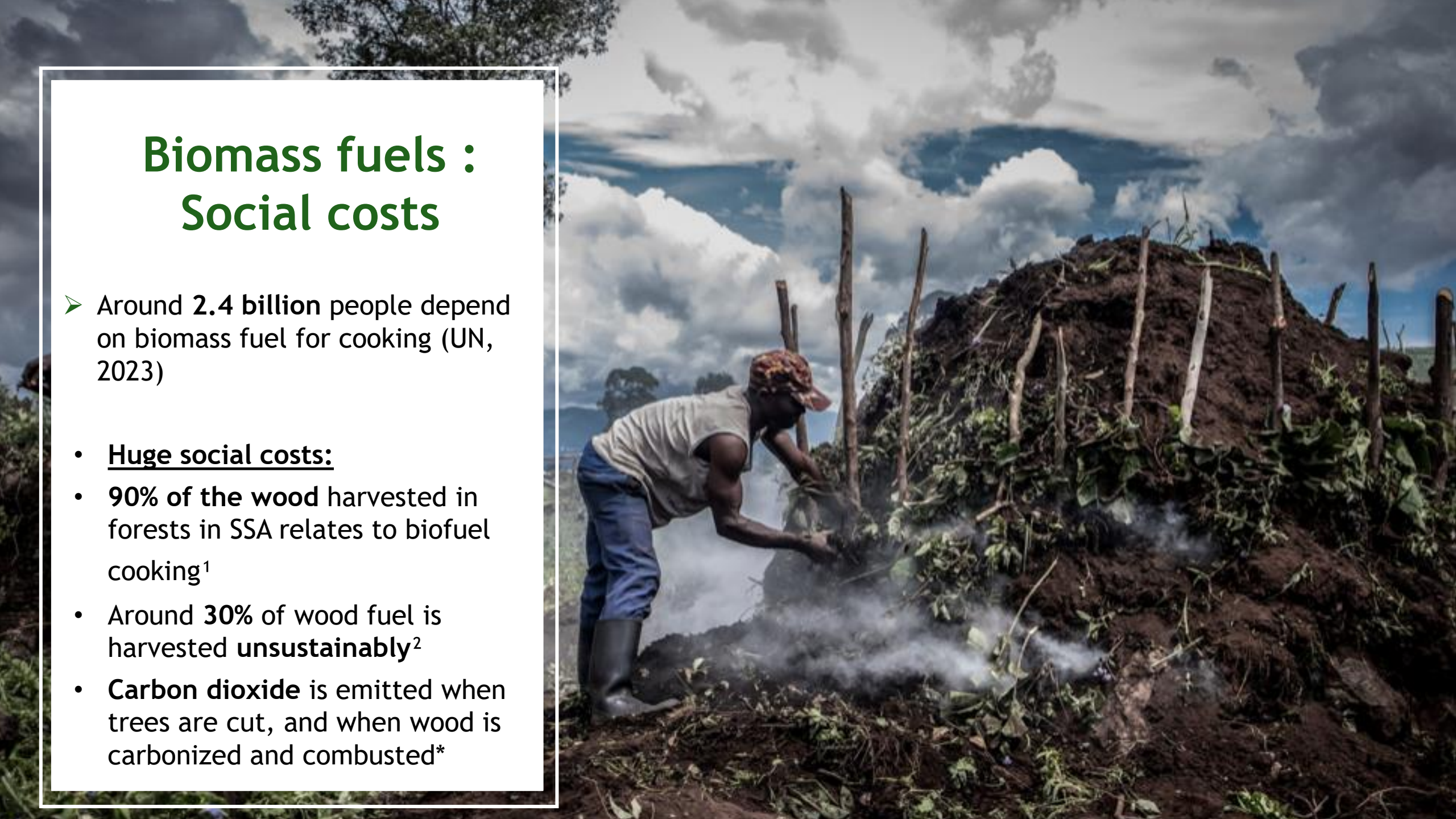
- **Huge social costs:**
- **90% of the wood** harvested in forests in SSA relates to biofuel cooking[1]
- Around **30%** of wood fuel is harvested **unsustainably**[2]
- **Carbon dioxide** is emitted when trees are cut, and when wood is carbonized and combusted*



Biomass fuels : Private costs

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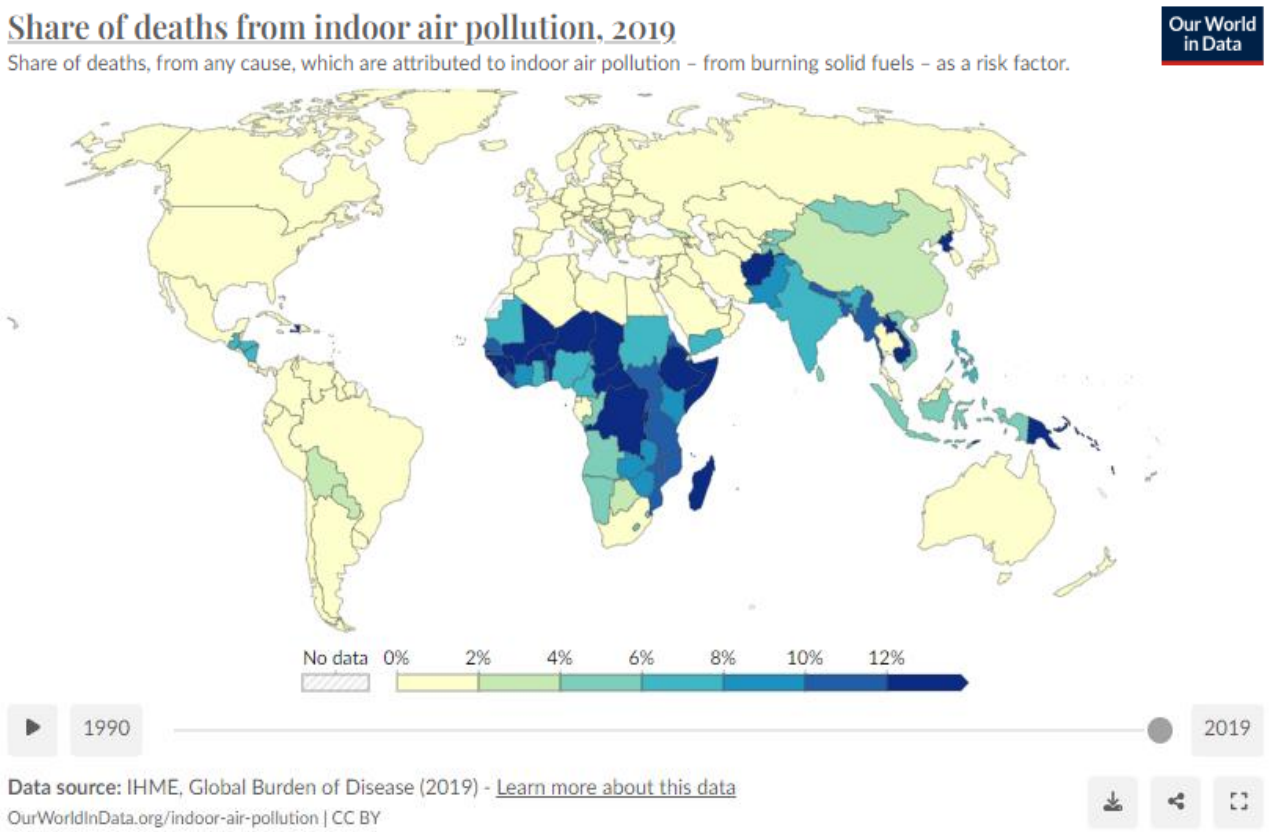
- <u>Huge private costs:</u>
  - Indoor air pollution estimated to kill around **2 to 4 million** people each year [1]



- Share of deaths from indoor air pollution reaches 12% in some countries [1], disproportionnately women

- Lower birthweight & height-for-age, increasing risk of negative health outcomes throughout life[2]

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  - Burden mostly falls on **women**: most involved in cooking & collecting wood ('time poverty')[2]
  - If not 'collected for free', more and more **expensive**: 3.5% of income for the median American household, versus 20% of income for median Kenyan urban hh[3]

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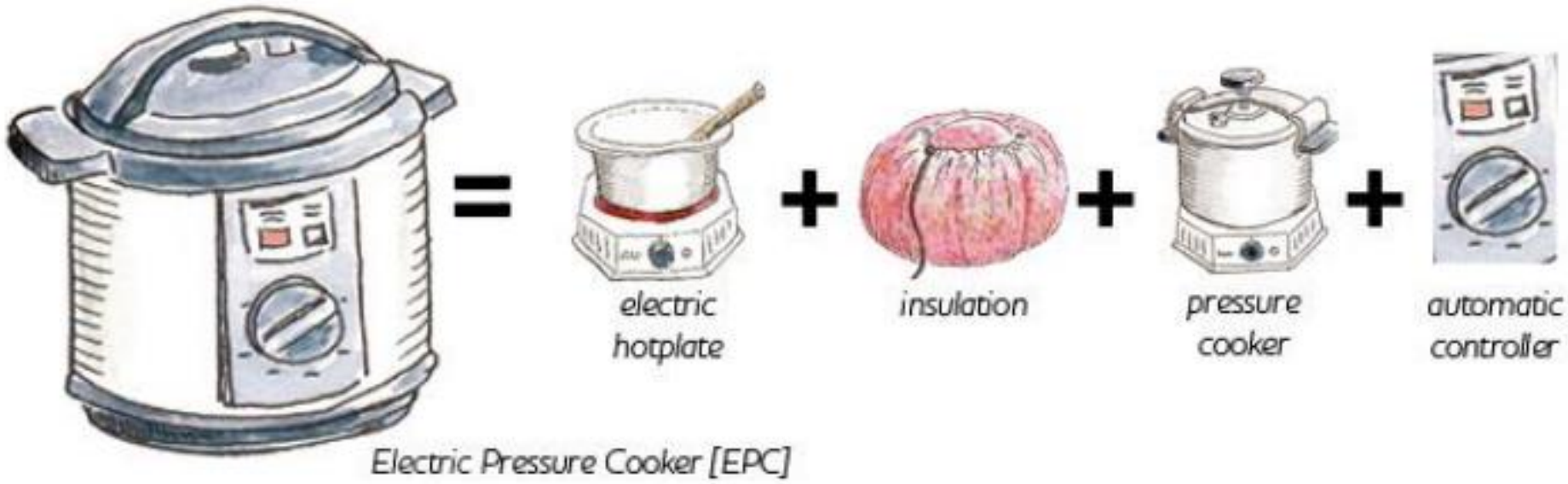
Batchelor et al, 2019



Electric Pressure Cooker [EPC]

Electric Pressure Cookers

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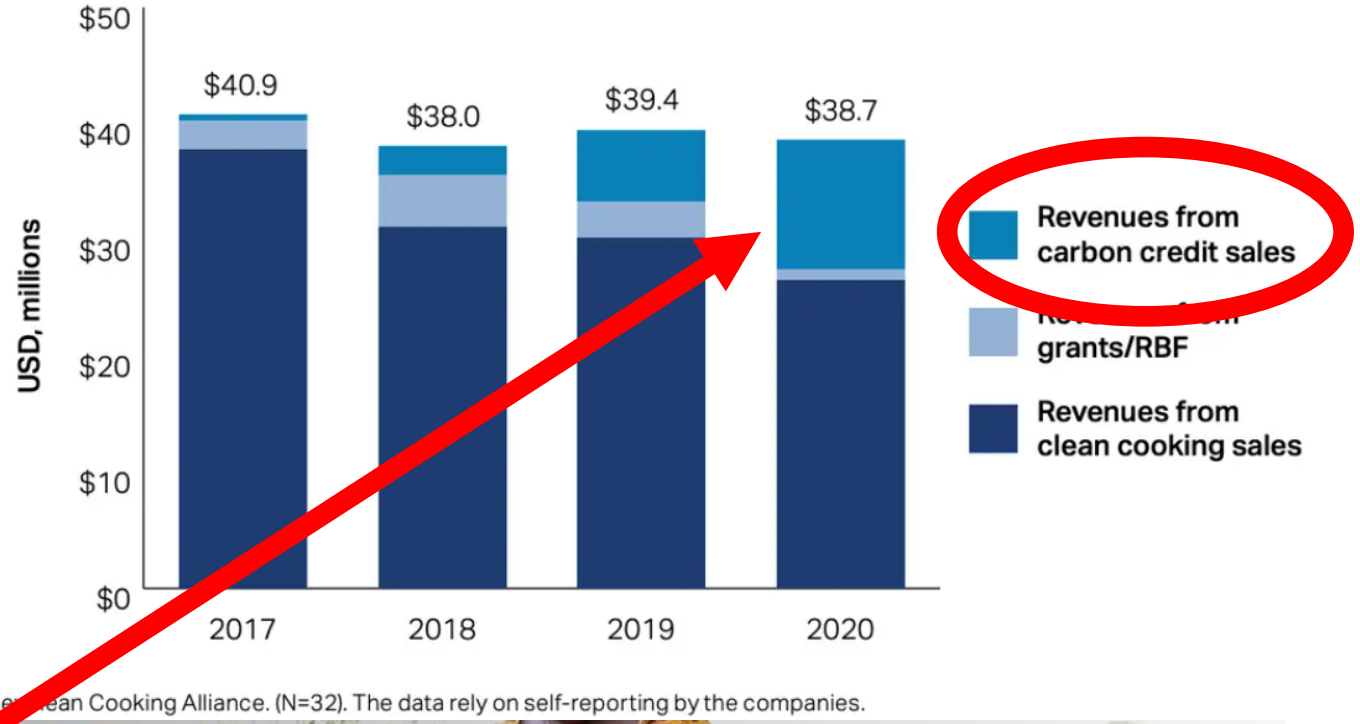
- But, now electric cooking much more cost-efficient, e.g. **EPC = hotplate + insulation + pressure → twice as efficient** as a hotplate + cheaper[3]
- **Carbon credits**

Importance of carbon credits to ‘green cookstoves’ companies has increased over past years



Source: Clean Cooking Alliance. (N=32). The data rely on self-reporting by the companies.

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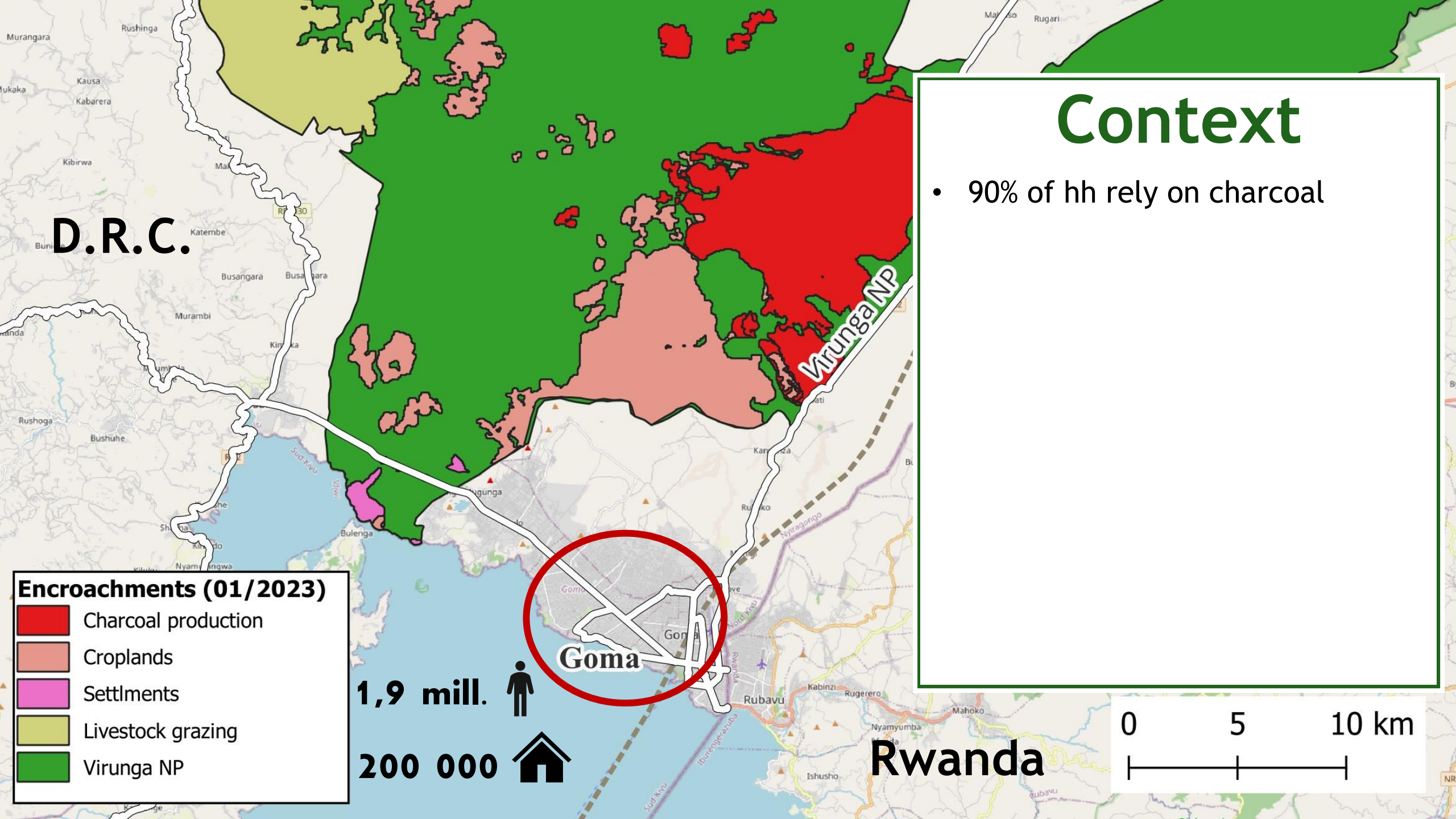
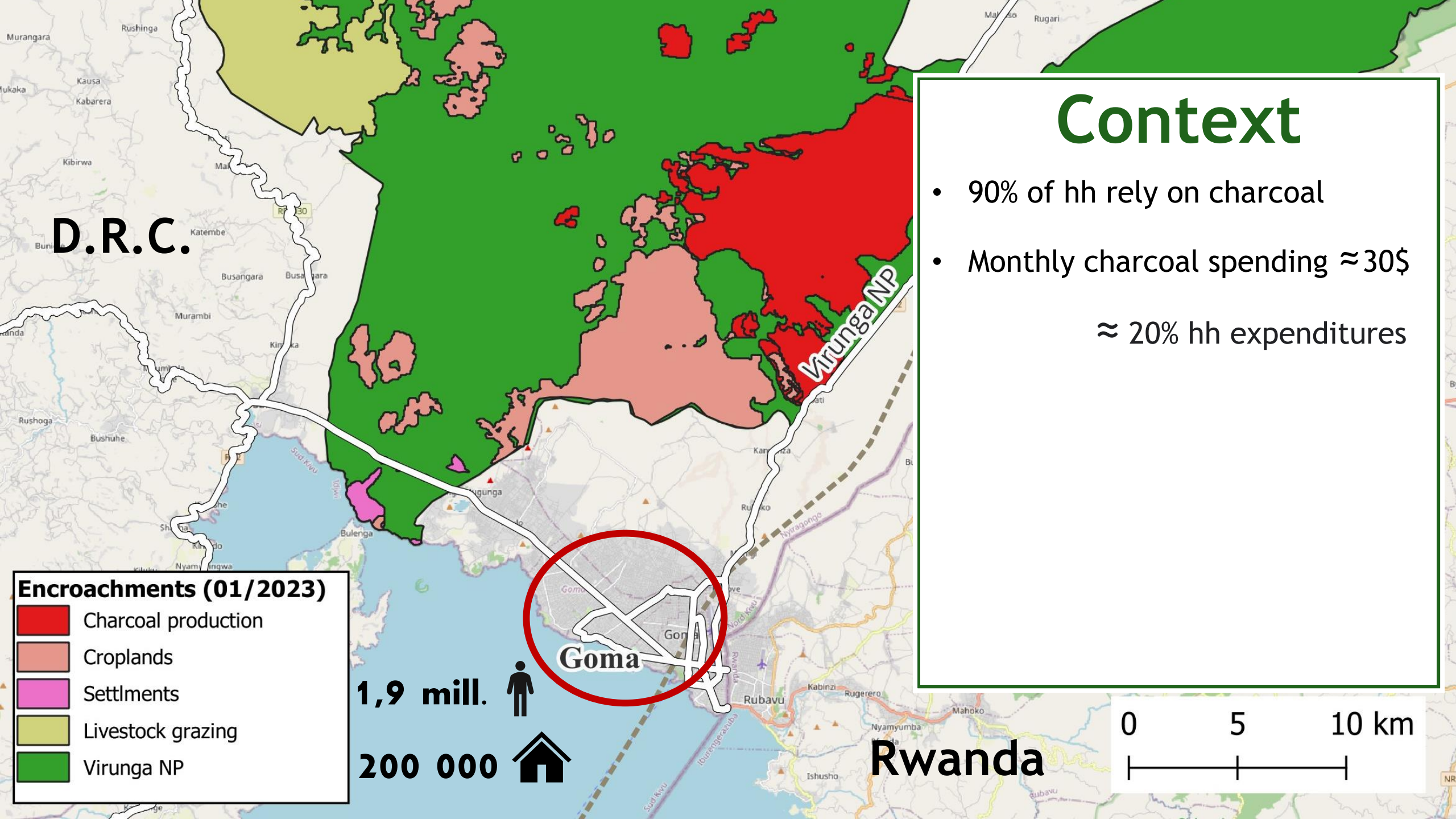
- Today, electric cooking much more cost-efficient, e.g. **EPC = hotplate + insulation + pressure → twice as efficient** as a hotplate + cheaper [3]
- **Carbon credits**
- **Other barriers however[4]:**
  - ✓ Sticky habits
  - ✓ Unknown (future) benefits
  - ✓ Unreliable products
  - ✓ Intra-household bargaining



Context

- 90% of hh rely on charcoal



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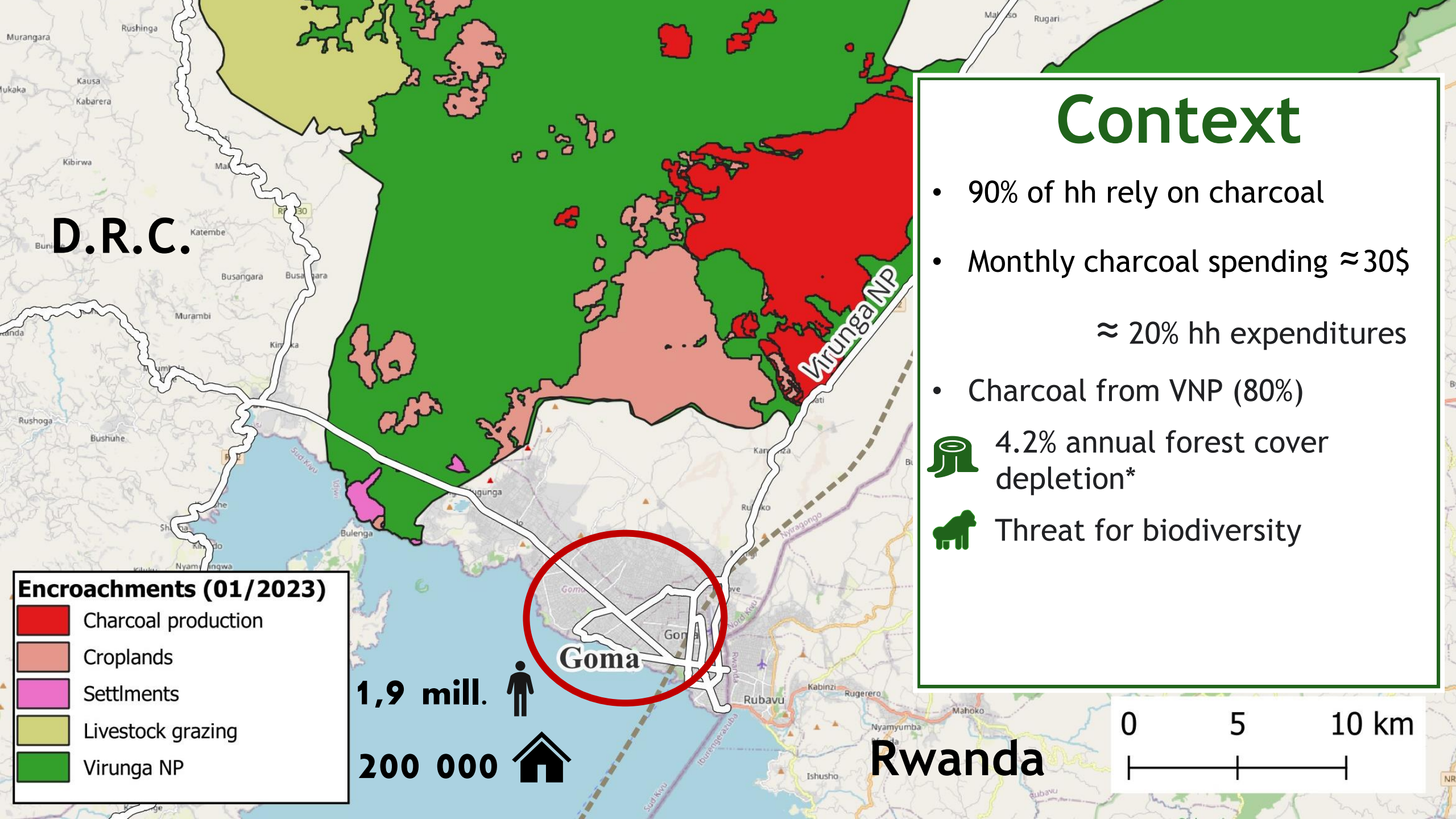
- 90% of hh rely on charcoal
- Monthly charcoal spending ≈30$

  ≈ 20% hh expenditures



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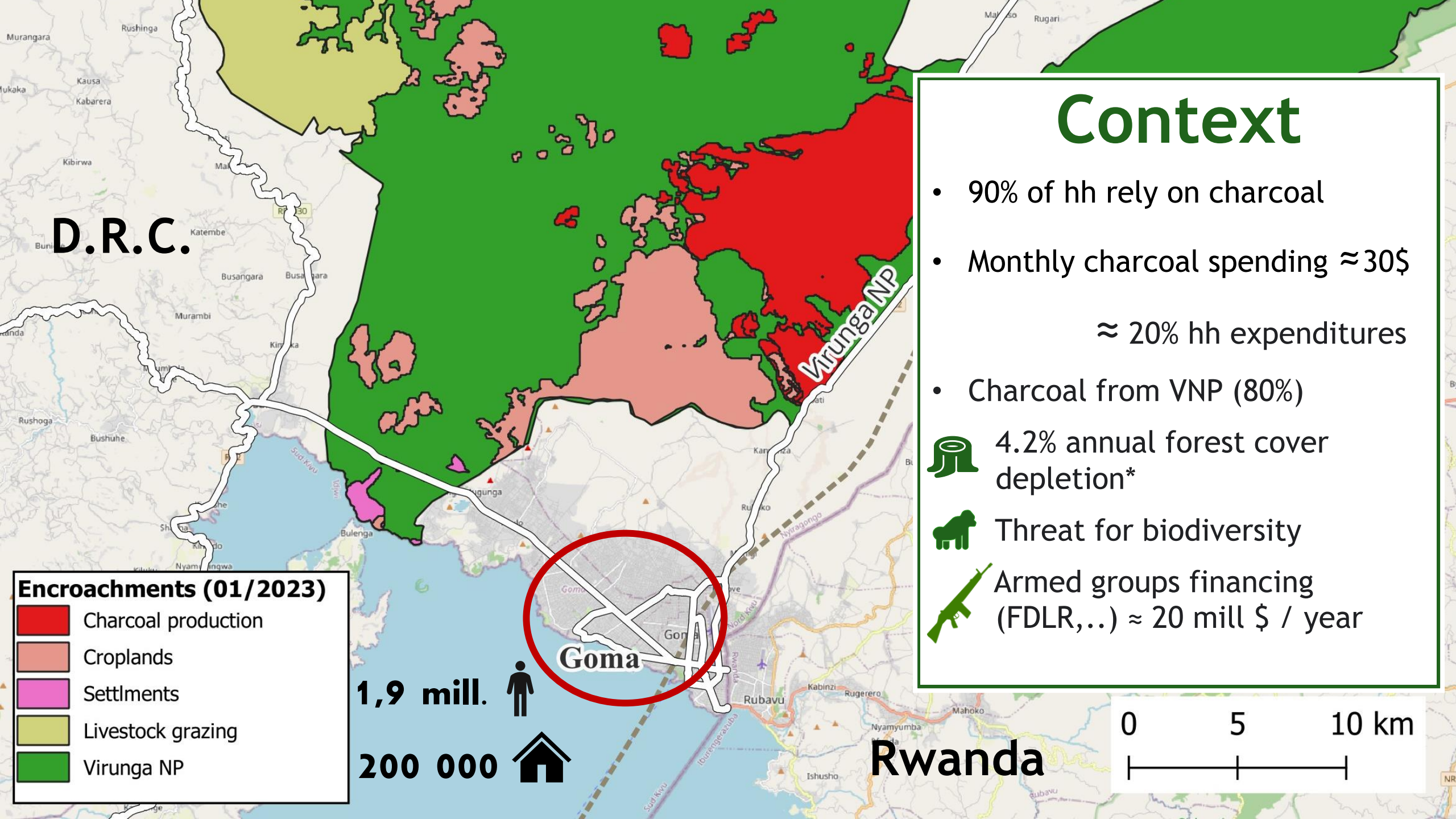
- Charcoal from VNP (80%)

4.2% annual forest cover depletion*

Threat for biodiversity



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Threat for biodiversity

Armed groups financing (FDLR,..) ≈ 20 mill $ / year

Demand for electric cooking?

- Since 2019, **30,000 hh** have gained access to **reliable, green, pre-paid** electricity from Virunga Energies (VE) → 60,000hh (2025)

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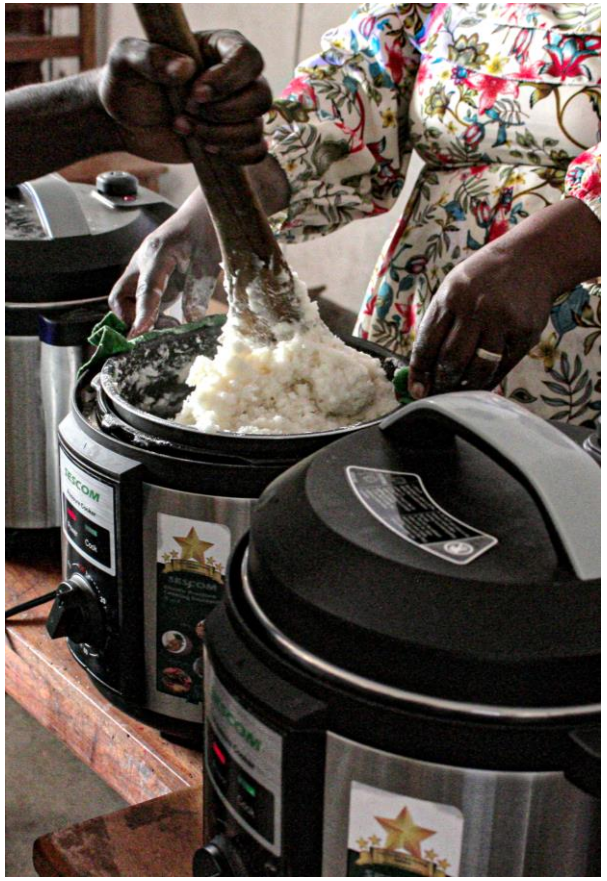
- Yet, very few rely on electricity for cooking
- **No EPC available** on the market
  - RCT to test a distribution model **with 100% subsidy (VE)**
  - Explore **mechanisms** that drive adoption **(Nudge & voucher)**
  - Estimate impact on **energy consumption**, then derive **environmental effects**

Main treatment: EPC (N=1000)

- Beneficiaries receive an **Electric Pressure Cooker (worth 80$)** for free
- Primary cook attends a **2-hour demonstration session**
- **3 ambassadors visits**
- **Cookbook** in Swahili

Recipes & Tips

Cook together



Electricity Voucher (N=500)

- Encourage trying-out EPC
- Risk-averse budget constrained households
- **5$ electricity voucher** from Virunga Energies

Environmental nudge (N=500)

- Park ranger present at demonstration session
- Sticker on EPC (nudge)

Randomized Controlled Trial

- Pre-select **1500** households : **Virunga Energies clients** (3-30$ monthly) + charcoal as main fuel
- Pre-intervention **survey**
- **Stratification:** charcoal & electricity spending
- **Randomization** : 1000 EPC + demo

  + 500 control
- **4 treatment arms** (Nudge + voucher)

Treatment		Nudge	No nudge	Control
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- **Cluster** randomization **(150m)**

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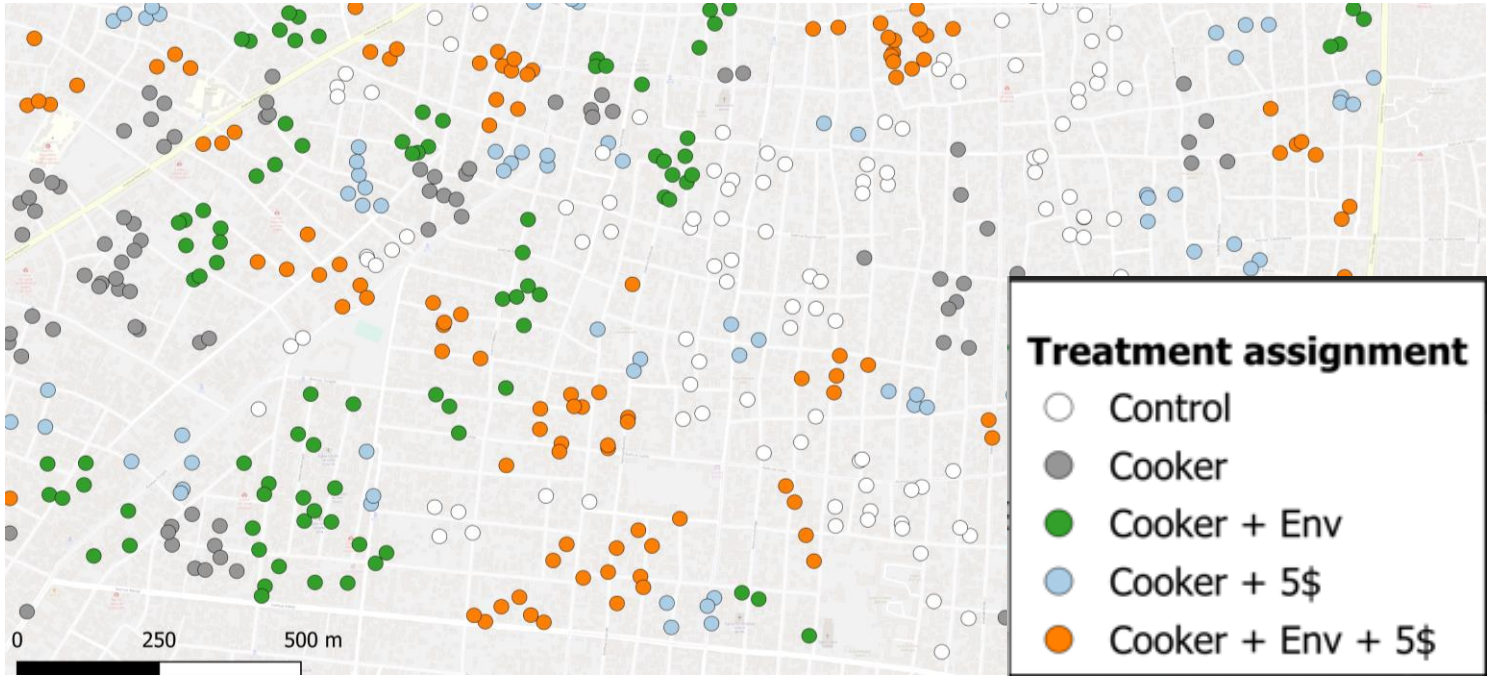
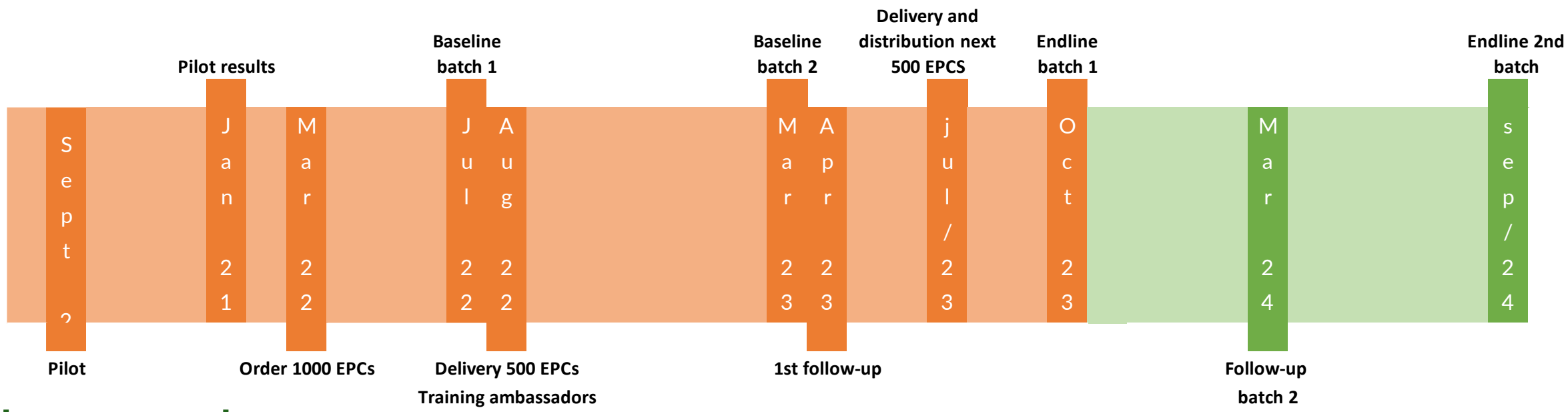


Logistics → 2 x 500

Timeline



Pilot ?
+ 35% of meals
+ 5.6 US$ (+25%) electricity

Distribution 1/2

Distribution 2/2

➡ Results from 1st batch!

Outcome variables (+ 6 and + 12 months*)

Outcome family	Variable
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ASH WEIGHING

Household survey data (+ 6 and + 12 months*)

- 50’ survey
- 2 visits: main survey & ashes (+7 days)
- April 2023 & October 2023

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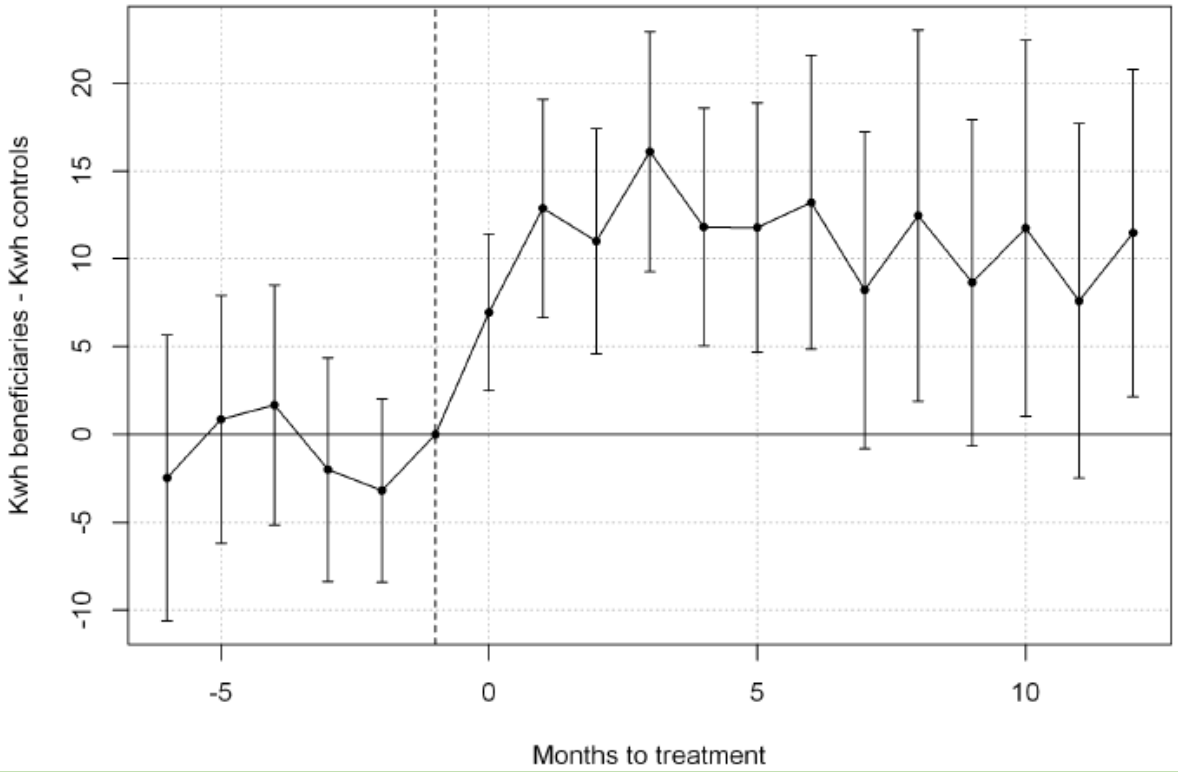
Other socio - economic outcomes	• Cooking time (survey) • Self-reported health outcomes (survey)

Electricity consumption

$$kwh_{i,t} = \beta_0 + \sum_{t=-6}^{12} \beta_t \cdot Cooker_i, t + \gamma_i + \lambda_t + \epsilon_{i,t}$$



- **+10Kw/H electricity monthly (+21%) ≈ $2,5**
- Equivalent of **13,5 FULL meals ***
- **48% of meals** (partially) cooked with EPC
- **+33,6% elec** as primary cooking energy

	kwh / month	main enegy elec	meals with EPC (% 7d)
ITT +12 months			
EPC	9.871+	0.336***	0.486***
	(5.322)	(0.028)	(0.021)
Mean control	47	0.03	0
Num.Obs.	15610	749	749
ATT +12 months			
EPC	11.975*	0.363***	0.495***
	(5.520)	(0.028)	(0.021)
Mean control	47	0.02	0.02
Num.Obs.	15610	749	749

CHARCOAL CONSUMPTION

- **-33,5 gr ashes**/day (29% reduction) **≈ -507 gr/day**

  ≈ -188 kg/year

- **+3,5% no charcoal** used
- **-6,6$** charcoal/month (-22% spending)

$$y_i = \beta_0 + \beta_1 \cdot Cooker_i + \gamma X_i + \epsilon_i$$

	ashes (g /day)	ashes (log)	No ashes (dummy)	Main energy biomass (dummy)	Spending charcoal (usd)
ITT +12 months					
EPC	-33.590***	-0.484***	0.035**	-0.321***	-6.622***
	(8.440)	(0.074)	(0.012)	(0.031)	(0.979)
Mean control	116	4.53	0.04	0.9	26.03
Num.Obs.	749	726	749	749	749
ATT +12 months					
EPC	-40.347***	-0.542***	0.038**	-0.348***	-7.076***
	(7.930)	(0.072)	(0.012)	(0.032)	(0.923)
Mean control	116	4.54	0.04	0.9	26.01
Num.Obs.	749	726	749	749	749

BRINGING RESULTS TOGETHER

Electricity consumption	% meals cooked with EPC	Charcoal consumption	Charcoal spending	LPG spending
+21% | 2,5$	+48%	-29%	-22% | -6,6$	-1,5$

- Evidence of **energy stacking**
- EPC used to cook **components of meals** (rice, foufou, meat, …)
- Purchase smaller quantities of charcoal at the time – more expensive for same weight
- Monthly savings **-5,6$**
- **Total savings (EPC lifetime 5y) ≈ 336$**

PRO-SOCIAL MOTIVATIONS

- **+ 40% donated to charities**
- +15% locus of control (1-10)
- **13% less likely** to use **charcoal from the park**
- **47% less likely** to claim that **making charcoal in VNP = acceptable**

$$y_i = \beta_0 + \beta_1 \cdot Cooker_i + \gamma X_i + \epsilon_i$$

	Donation (usd)	Locus (1-10)	Illegal charc (dummy)	Agree (dummy)
ITT +12 months				
EPC	0.208*	0.266+	-0.075*	-0.123***
Mean control	0.55	1.8	0.57	0.26
	(0.087)	(0.142)	(0.034)	(0.031)
Num.Obs.	741	745	749	749
ATT +12 months				
EPC	0.251**	0.386**	-0.078*	-0.152***
	(0.084)	(0.139)	(0.035)	(0.030)
Mean control	0.55	1.8	0.57	0.27
Num.Obs.	741	745	749	749

*Note: Stratification variables are included in controls. Columns (3) and (4) report the marginal effect calculated at mean. Standard errors clustered at the randomization cluster level. +=.1, *=.05, **=.01, ***=0.001.*

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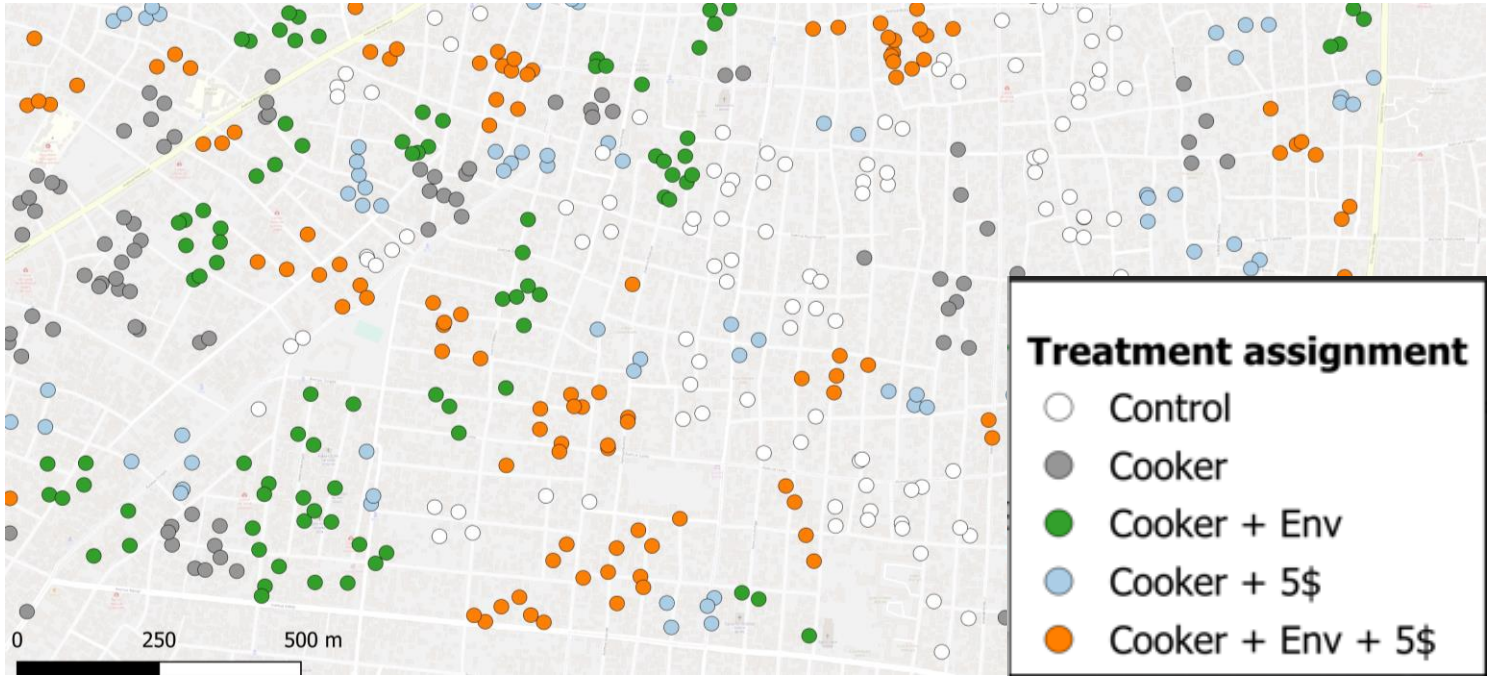
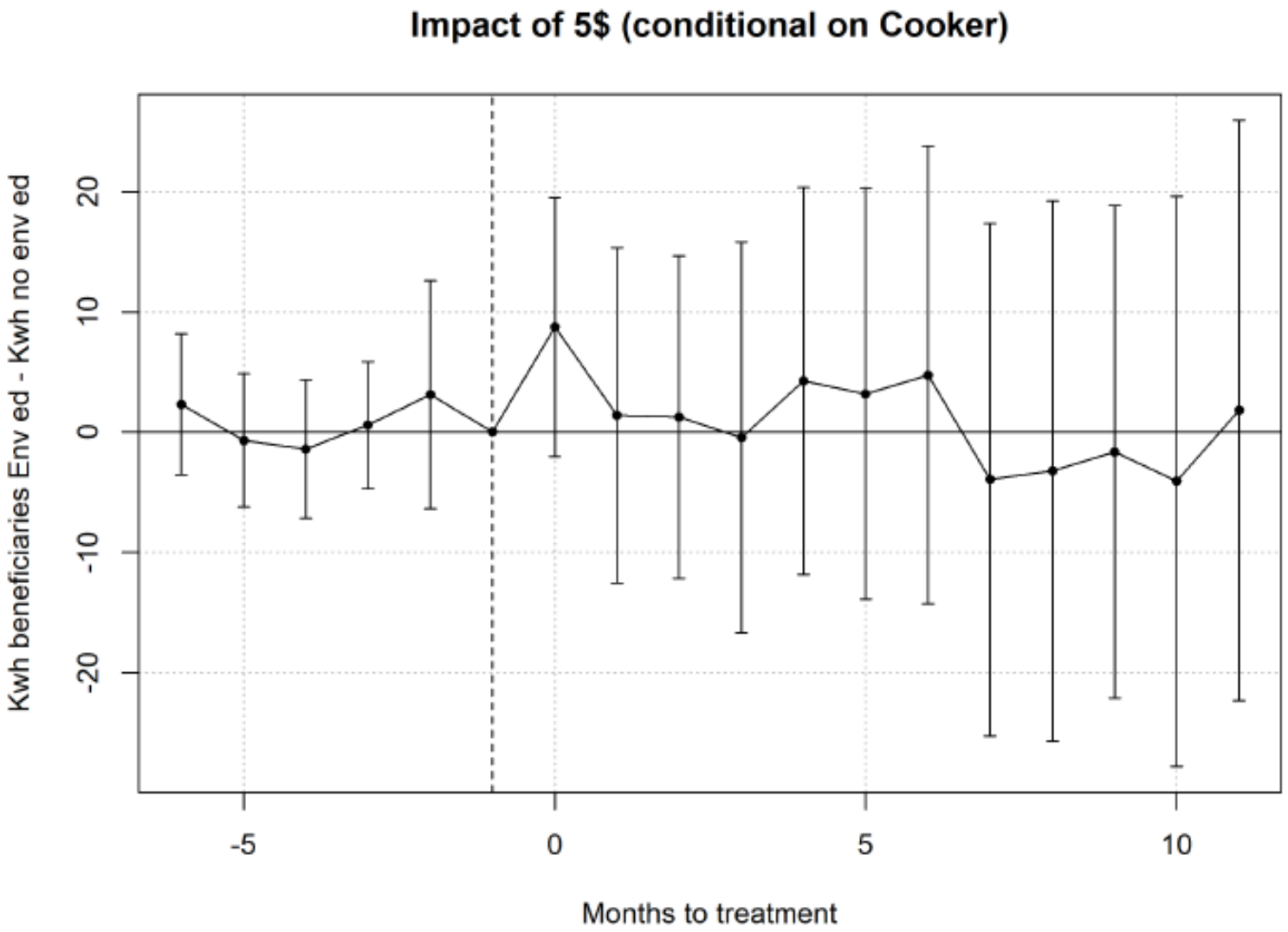


IMPACT OF FINANCIAL INCENTIVE

$5 of free electricity, control = cooker

➡ Zero impact



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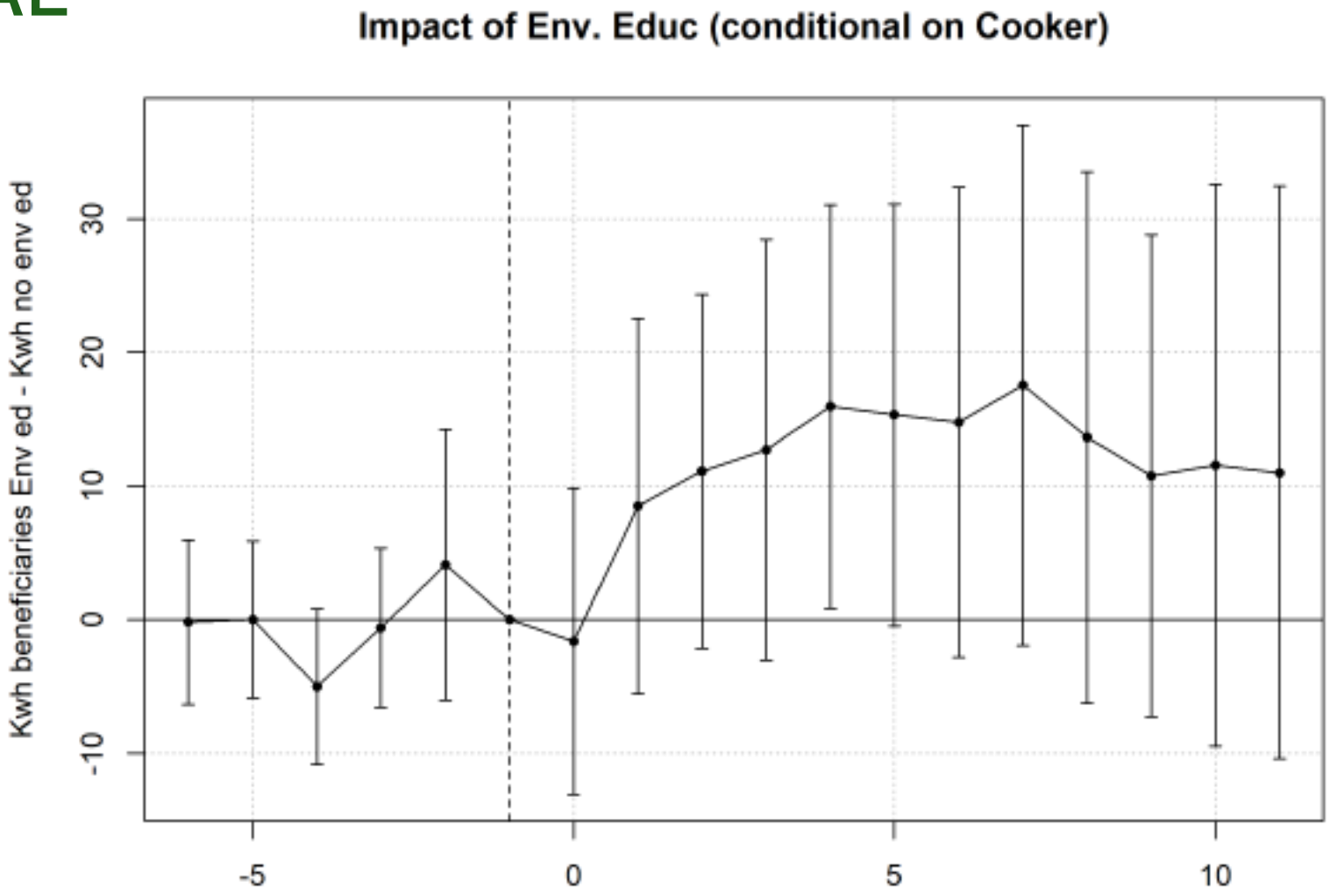
Variable	Mean Cooker no voucher	Voucher (β_2)	p-value
Meals with EPC (% 7d)	0.439	-0.002	0.972
Main energy electricity	0.489	-0.001	0.984
Meals with charcoal (% 7d)	0.557	0.021	0.548
Main energy charcoal	0.443	0.007	0.870
Daily Ashes (g - prelim)	82.423	15.704	0.113
Charcoal spending Month (usd)	21.117	1.551	0.327
Main energy LPG	0.051	-0.020	0.347
Daily cooking time (min)	157.959	7.982	0.250
Food security (FAO)	42.215	0.111	0.890
Reported illness	0.930	0.155	0.241

IMPACT OF ENVIRONMENTAL TRAINING

- Imprecise zero



IMPACT OF ENVIRONMENTAL TRAINING

$$y_i = \beta_0 + \beta_1 \cdot Cooker_i + \beta_2 \cdot EducEnv_i + \gamma X_i + \epsilon_i$$

- Additional impact on reduction charcoal use and time savings

Variable	Mean Cooker -no Educ	Env. Educ (β_2)	p-value
Meals with charcoal (% 7d)	0.603	-0.065	0.065
Main energy charcoal	**0.503**	**-0.087**	**0.04**
Charcoal spending Month (usd)	22.667	-1.398	0.377
Daily Ashes (g)	**104.946**	**-26.759**	**0.007**
Main energy LPG	0.041	0.008	0.770
Daily cooking time (min)	**173.511**	**-21.177**	**0.003**
Reported illness	1.007	0.004	0.975
Food security (FAO)	41.993	0.513	0.532

COST-BENEFITS ANALYSIS

COST

Cost per cooker (cooker + transport + distribution + ½ voucher + ambassadors visits) = **$ 94**

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Electricity consumption : +10kwh /mo.

- For hh: **$5.6 savings/mo = $302 over 5 yrs** (10% discount rate)
- For firm: 1kwh = 0.21usd of revenues → $2.5/mo = **$150 over 5 years**

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- 500 EPC = 1-2ha of avoided deforestation (biodiversity, to be refined + general equilibrium effect)
- **LCA**: **1 EPC ≃ 6,3t CO2e** avoided (Social Benefit ≃ **$315** for a SCC of $50) (using FAO 2017)

(NON-)MONETARY BENEFITS

- Comparison Ecooker-Charcoal among beneficiaries
  - ✓ 88% find Ecooker cheaper
  - ✓ 90% find Ecooker faster (-26min daily, 83% multitask)
  - ✓ 90% find Ecooker easier to use

- Changes in daily life?
  - ✓ Cleaner (Air + dirt)
  - ✓ Faster
  - ✓ Safer

SCALE UP ?

Informing EPC upscaling

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WP1: Deepening

Exploring potential of larger EPCs in Goma

SCALE UP ?

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WP1: Deepening

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WP2: Broadening

Expanding EPC distribution to rural areas

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Exploring potential of larger EPCs in Goma

WP2: Broadening

Expanding EPC distribution to rural areas

WP3: Maintaining

Experimenting with repair & maintenance service

SCALE UP ?

Informing EPC upscaling

WP1: Deepening

Exploring potential of larger EPCs in Goma

WP2: Broadening

Expanding EPC distribution to rural areas

WP3: Maintaining

Experimenting with repair & maintenance service

WP4: Marketing

Examining WTP and its determinants

Any questions?

Virunga Foundation (DEVCO / USAID grants) = cookers and staff

PEDL & CDC (Co-financing impact evaluation)

FID (Impact evaluation)

FWO (Wages Antwerp team)

Balance check

	Control (N=560)		EPC (N=1034)			
	Mean	Std. Dev.	Mean	Std. Dev.	Diff. in Means	Std. Error
Gender (Female = 1)	0.90	0.30	0.86	0.35	-0.04*	0.02
Age	37.33	12.48	38.48	12.73	1.15+	0.66
HH size	8.34	3.05	8.31	3.07	-0.04	0.16
Number lunches / week	6.26	1.97	6.27	2.00	0.01	0.10
Ladder life (Cantril)	4.47	1.29	4.37	1.25	-0.10	0.07
Electricity 2^{nd} source energy	0.17	0.37	0.15	0.35	-0.02	0.02
Food consumption score (FAO)	40.79	7.98	40.12	7.92	-0.67	0.42
Index goods ownership	4.68	1.15	4.58	1.11	-0.09	0.06

Cookers and electricity consumption 6 and 12 months after intervention

	kwh / month	main enegy elec	meals with EPC (% 7d)
ITT +6 months			
EPC	10.960***	0.485***	0.432***
	(2.441)	(0.026)	(0.023)
Mean control	46	0	0
Num.Obs.	17309	750	753
ATT +6 months			
EPC	11.387***	0.514***	0.464***
	(2.460)	(0.026)	(0.023)
Mean control	47	0.01	0
Num.Obs.	17309	750	753

	kwh / month	main enegy elec	meals with EPC (% 7d)
ITT +12 months			
EPC	9.871+	0.336***	0.486***
	(5.322)	(0.028)	(0.021)
Mean control	47	0.03	0
Num.Obs.	15610	749	749
ATT +12 months			
EPC	11.975*	0.363***	0.495***
	(5.520)	(0.028)	(0.021)
Mean control	47	0.02	0.02
Num.Obs.	15610	749	749

Note: Stratification variables are included in controls. Standard errors clustered at the randomization cluster level. +=.1, *=.05, **=.01, ***=0.001

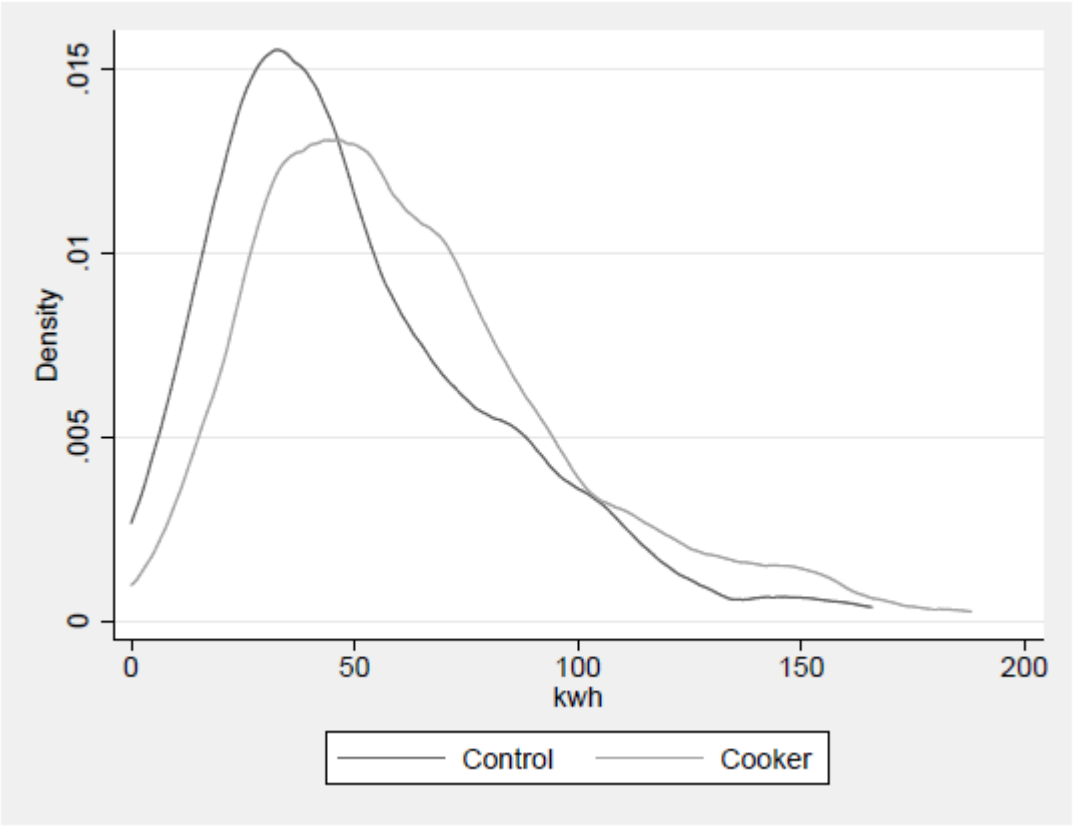
Cookers and charcoal consumption 6 and 12 months after intervention

	ashes (g /day)	ashes (log)	ashes (dummy)	Main energy biomass (dummy)	Spending charcoal (usd)
ITT +6 months					
EPC	-41.473***	-0.408***	0.054***	-0.437***	-6.635***
	(8.732)	(0.070)	(0.015)	(0.030)	(1.151)
Mean control	136	4.66	0.02	0.9	29.54
Num.Obs.	753	713	753	750	753
ATT +6 months					
EPC	-47.200***	-0.472***	0.056***	-0.456***	-7.439***
	(8.235)	(0.068)	(0.014)	(0.030)	(1.086)
Mean control	136	4.68	0.02	0.9	29.67
Num.Obs.	753	713	753	750	753

	ashes (g /day)	ashes (log)	ashes (dummy)	Main energy biomass (dummy)	Spending charcoal (usd)
ITT +12 months					
EPC	-33.590***	-0.484***	0.035**	-0.321***	-6.622***
	(8.440)	(0.074)	(0.012)	(0.031)	(0.979)
Mean control	116	4.53	0.04	0.9	26.03
Num.Obs.	749	726	749	749	749
ATT +12 months					
EPC	-40.347***	-0.542***	0.038**	-0.348***	-7.076***
	(7.930)	(0.072)	(0.012)	(0.032)	(0.923)
Mean control	116	4.54	0.04	0.9	26.01
Num.Obs.	749	726	749	749	749

Note: Stratification variables are included in controls. Standard errors clustered at the randomization cluster level. +=.1, *=.05, **=.01, ***=0.001

Heterogeneity



- Entire distribution moved
- Baseline wealth, family size, electricity consumption *etc* don't explain much of the observed adoption (regression setting)
- 20% of beneficiaries are using the cookers occasionally or not using it
- Exploratory PCA : 6 - 8 quite different subgroups, including poor households with high usage
- +12mo : +10% of the cookers not functioning (but easily repairable)

Breakdown & repairs

- 84% (353) des cuiseurs fonctionnent parfaitement, 15% (63) ont un problème. Parmi ceux-là, il est complètement hors d'usage pour 44 ménages (70%), et utilisable avec des limitations pour 27% d'entre eux (17). Utilisable occasionnellement pour 2 (3%).
- Since distribution: 161/419 (38%) ont eu un problème technique au moins une fois. Parmi ces 161: 48.5% ont eu des problèmes de multiprise/cable
- Parmi ces 161, 98 (61%) ont cherché une solution et, 91 (57%) disent que le problème a été résolu.
- En moyenne, la réparation a couté 2.9$. Mais sur les 35 (39%) n'ont pas du payer du tout, donc en excluant les réparations gratuites, on arrive à 4.8$ en moyenne de réparations.
- Parmi ceux qui ont fait réparer, 26.5% ont été dans un repair shop, 17% l'ont réparé eux-mêmes, 16% ont demandé à des proches bricoleurs, 11% électronicien, et 29% autre(achat de nouveau multiprise ou appel aux réparateurs virunga pour la majorité de ce groupe)
- La principale raison citée pour n'avoir pas cherché à le faire réparer est que les bénéficiaires ne savaient pas ou aller le faire réparer (50%). Dans 13% des cas, l'appareil fonctionnait quand meme,11% mentionnent un oubli, et 9.5% n'avaient pas les moyens.
- Les gens payent en moyenne 18.3% du prix d'achat d'un appareil pour le faire réparer. -> 12-13$ pour les cuiseurs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Research objectives & contribution

- RCT to test a distribution model of **EPC with a 100% subsidy**
- Estimate impact on **energy consumption & development** outcomes, then derive **environmental effects**
- Explore mechanisms that may enhance adoption:
    - **5USD electricity voucher** to encourage risk-averse hhs to try out the EPC
    - **an environmental awareness training** to test whether knowledge about social costs increases adoption