



# MAGC Research Webinar: Smart-Metering Around the World

21 May 2025



# MAGC Research Partners

Funded by:



UK Government



Department for  
Energy Security  
& Net Zero

## Smart-Metering Studies Central Research Team:



## Local Research Teams:



UNIVERSITY OF CAPE TOWN  
IYUNIVESITHI YASEKAPA • UNIVERSITEIT VAN KAAPSTAD

miyamoto.



UNSW  
SYDNEY



Embodied  
Carbon Study:

ARUP

# Speakers



**ELAINE REINKE**

MAGC Research Lead, International Finance Corporation (IFC)



**SIMON ELAM**

Director of the Smart Energy Research Group, University College London (UCL)



**GRANT SMITH**

Senior Research Officer, University of Cape Town, Energy Systems Research Group



**MARTIN PULLINGER**

Senior Research Fellow, UCL



**MARIA CARRIZOSA** Senior Urban Planner  
Climate Resiliency Experts, Miyamoto International LLC



**CLARA ELISA HIDRON BOTERO**

Director of Strategy, Innovation and Sustainability, Conaltura



**EOGHAN MCKENNA**

Principal Research Fellow, UCL

with Gierlang Bhakti, Green Building Expert



**MATTHEW MUNRO**

Sustainability Consultant, Arup

# Agenda

- 1. Opening Remarks: Monica Poletti (UK Government, Department for Energy Security & Net Zero)**
- 2. Smart Metering: Global (Simon & Martin)**  
Overall Research Design of the smart metering impact evaluations
- 3. Smart Metering: South Africa (Grant)**  
South African context, Key findings and lessons from the pilot, Meter level administrative data sets, Apartment level panel survey, and additional sensors – data strategy in the main phase
- 4. Smart Metering: Colombia (Maria & Clara)**  
Results and lessons learned from the pilot phase, next steps for the main phase
- 5. Smart Metering: Indonesia (Eoghan & potentially Gierlang)**  
Background to Indonesian context, Unique aspects about ID built environment, Insights from the pilot, Metering challenges and solutions, Site selection
- 6. Embodied Carbon (Matthew)**  
Embodied carbon in new building materials (concrete, steel, timber, bamboo) – overview of project methodology and progress
- 7. Questions & Answers**
- 8. Short feedback Survey**

# Questions & Answers

→ Please post your questions in the meeting chat ←



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UK Government

**Kindly complete this short online feedback survey – thank you!**

Scan this QR code:



Or click on this link (see meeting chat):

<https://www.surveymonkey.com/r/Global-MAGC-Research-update-webinar-May-21-2025>



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**Study design**  
**University College London**  
**Central Research Team**

*EDGE is an innovation of IFC, a member of the World Bank Group.*



# Smart Energy Research Group

## University College London



*Data-driven research: investigating the drivers of energy demand in residential buildings*



**Minnie Ashdown**  
Indoor environmental  
modelling



**Cristian Dinu**  
Research Software  
Engineer



**Simon Elam**  
SERG Director



**Jessica Few**  
Data science &  
energy demand



**Clare Hanmer**  
Buildings &  
energy



**Frances Hollick**  
Energy & thermal  
performance of  
buildings



**Eoghan McKenna**  
Energy Demand



**Tadj Oreszczyn**  
Prof of Energy &  
Environment



**James O'Toole**  
Operations  
Manager



**Martin Pullinger**  
Data science &  
energy demand



**Ellen Zapata-Webborn**  
Data Science & End Use  
Energy Demand



**Lin Zheng**  
Energy &  
buildings

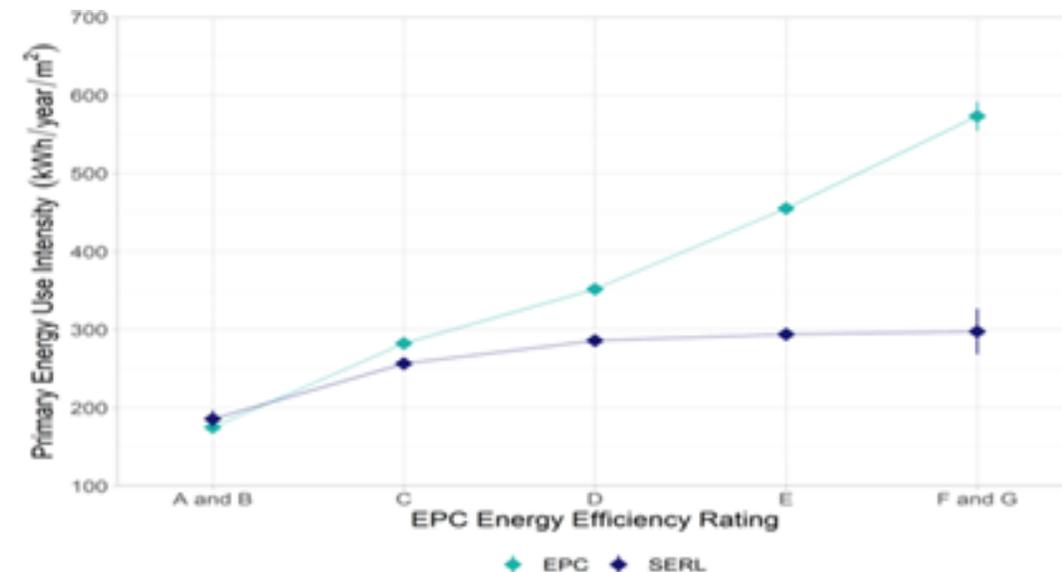
# Utilising smart meter data for research/evaluation

## Utilising smart meter data:

- We created the SERL Observatory (13k GB homes) - collect and manage smart meter data, linked to relevant contextual data
- Thus we have developed and refined methods for processing smart meter data, as well as analyses e.g.
  - statistical techniques such as regression and cluster analysis
  - machine learning techniques including elastic net regression, neural networks & extreme gradient boosting
  - building physics empirical analysis - Heat Transfer Coefficients and other physics-based techniques

## Research using smart meter data includes:

- evaluating building performance
- identifying energy poverty
- investigating energy demand profiles
- informing government policy
- recent SERL paper demonstrates that the Energy Performance Certificate model overpredicts energy use in C to G properties, and increasingly over predicts the change between bands



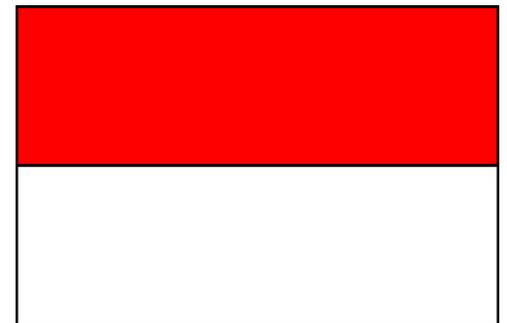
# MAGC EDGE Evaluation project: SERG role as Central Research Team

## Central Research Team (CRT) role:

- Overall research design
- Quantitative analyses
- Reports – midline and final

## CRT engagement with In-Country Teams (ICTs)

- We do *not* manage or oversee work of ICTs
- We do have regular and ongoing engagement with ICTs:
  - ensure consistency and understand differences across countries e.g. DHW key to EDGE savings in SA but irrelevant in Indonesia
  - optimise adaption of central research design into effective country-specific study manuals etc



# Study context

# EDGE: Excellence in Design for Greater Efficiencies

1.

**Free Software**



Further Resource: [EDGE Software Demo](#)

2.

**Achievable Standards**



Energy, Water,  
Embodied Carbon of Materials

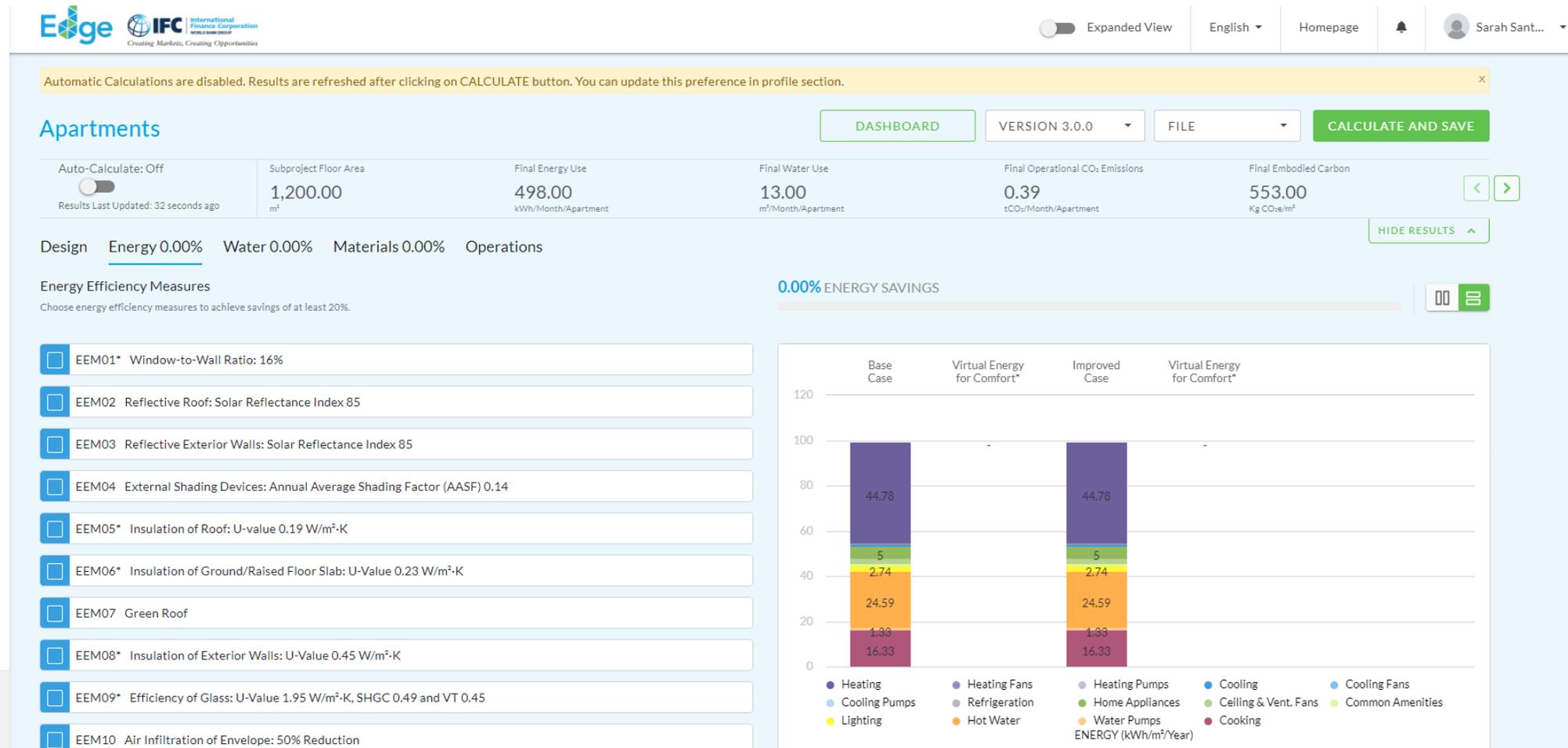
3.

**Verified Green Label**



# EDGE Compares Your Building to a Conventional Building

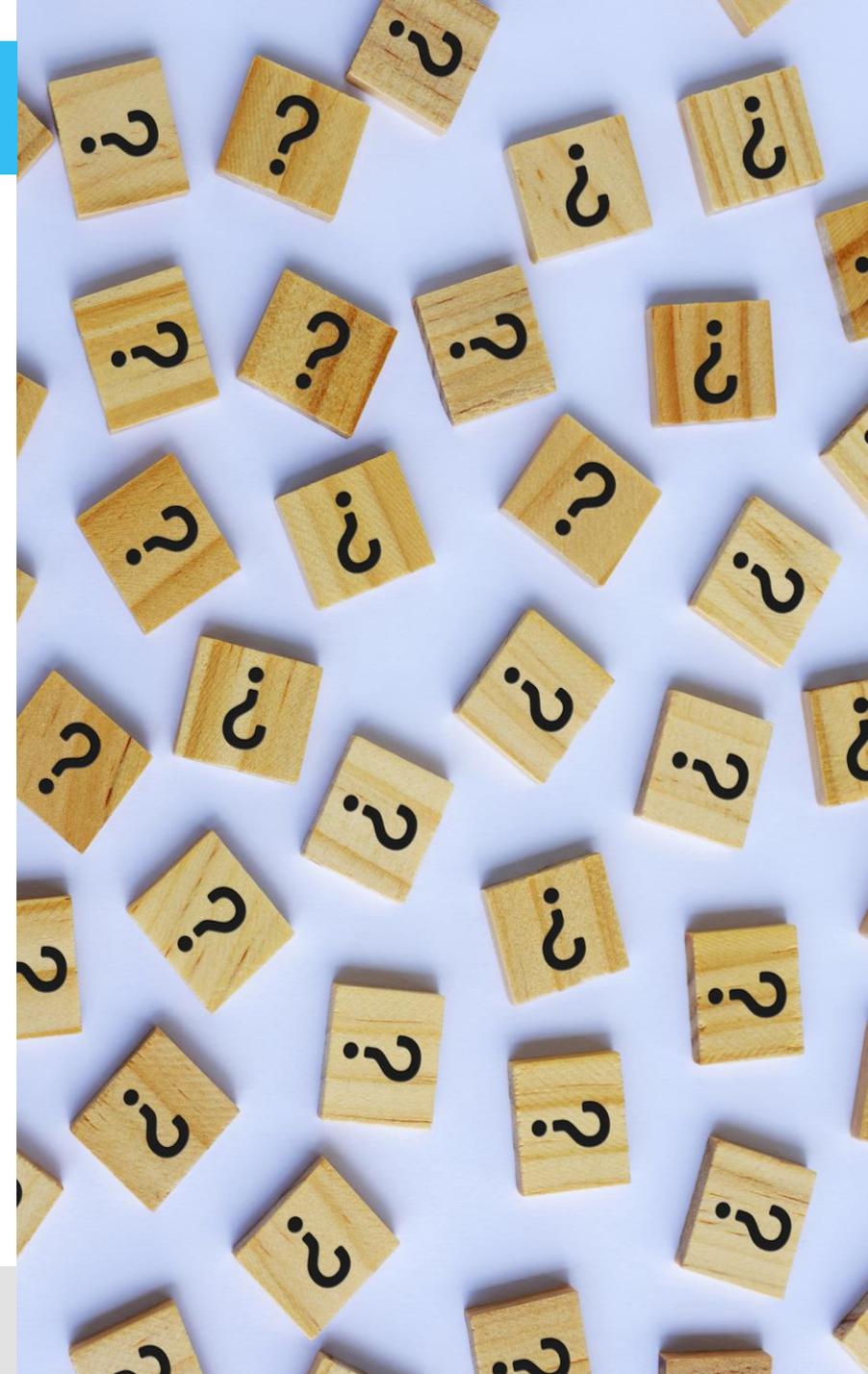
- Estimates annual energy and water intensity for the development
  - Overall and by major end uses
  - Savings compared to local equivalent conventional building



# Study design

# Research Questions

1. To what extent do IFC's EDGE certified buildings deliver **actual water (m<sup>3</sup>) and energy (kWh) savings compared with:**
  - (a) **EDGE predictions and**
  - (b) **conventional buildings?**
2. To what extent do the savings vary:
  - (a) between building types;
  - (b) over time;
  - (c) between green solutions (e.g. efficiency design approaches, technologies, operational practices)?
3. What are the main causes of observed variations in savings?
4. What can be done to increase the accuracy of predicted savings?
5. What can be done to increase actual savings?



# Site selection

- Suitable EDGE residential sites
- Matched counterfactual sites
- Data collected for residences in both sets of sites

- A selection of sites covering:
  - Main urban locations of EDGE buildings in the study country
  - Main EDGE solutions in use
  - Range of income bands

**EDGE**

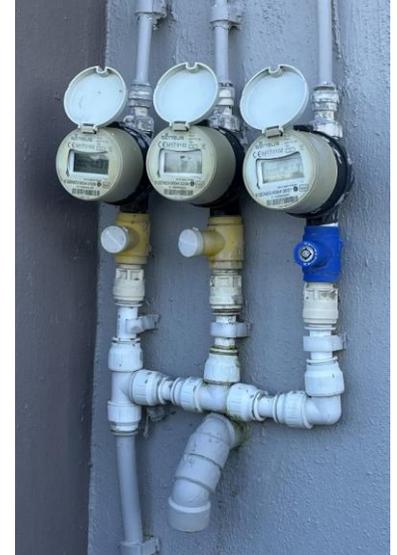
- Matched to EDGE sites by:
  - Location
  - Income band
  - Type of building
- Built close to local base case building standards

**Counter-factual**



# Data collection

- **Energy and water meter data** (n= 1000s)
  - Smart meter, or monthly manual readings
- Contextual data (n= 1000s)
  - **Participant survey** – demographics, building and appliance characteristics, energy- and water-using behaviours, etc.
  - **EDGE reports and site inspections** – building type, energy saving technologies, etc.
  - **Weather data**
- Sensor data (n = 100s)
  - **Indoor temperature and humidity**
  - **Energy/water uses for selected EDGE green solutions**, e.g. hot water electricity consumption (SA)



# Data analysis

1. Compare measured energy and water use between EDGE and counterfactual residences
2. Compare measured energy and water use with EDGE-predicted
3. Investigate variation in results by region, over time, & for main EDGE solutions in use
4. Identify factors which explain any observed performance gaps

 Insights for EDGE software and program design

# Two-stage study design

## Pilot phase

- Adapting study design to each country
- Learning and preparing for main phase, rather than answering the research questions
  - Trialling all aspects of study
  - Identifying sites, testing monitoring, survey design, etc.
  - Engaging with developers, site managers
- Small numbers of participants

## Main phase

- Mid-2025 to end 2026
- Full implementation of study
- Recruitment, data collection, data analysis
- Interim and final reporting





*Creating Markets, Creating Opportunities*



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# South Africa

## Evaluating EDGE nationally

**Grant Smith**  
**Richard Larmour**  
**Alison Hughes**

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## Contents

1. South African Context
2. Pilot Phase
  - a. Study Description, with some important elements noted
  - b. Some illustrative results
  - c. Insights
3. Main Phase
  - a. Research Questions
  - b. Research Design
  - c. Data Flow

## South African Context

## South African Context

- EDGE stock is almost entirely residential apartment blocks
  - Concentrated in the major metropolitan areas of South Africa
    - Cape Town
    - Gauteng
    - eThekweni and surrounding areas
- Local Building Standard (SANS 10 400 XA and SANS 10 400 XA2)
  - is the most appropriate “base case” for EDGE
  - Sets a high standard in terms of efficiency measured required
    - E.g. 50% of all energy used in hot water production needs to be from renewable sources
- Supply interruptions are a factor in historic and current data
  - Loadshedding (planned grid electricity outages)
    - Increasingly frequent, severe, and long lasting 2019 to March 2024, largely absent since May 2024.
  - Water-shedding (planned and unplanned water outages)
    - Increasingly prevalent in Gauteng municipalities, especially since 2023
    - Also present to some degree in eThekweni
- South African National Electricity Grid still coal intensive (80% +), although coal declining

Pilot Phase

# Pilot Study Elements

- Test Research methods and technology for Main Phase Study.

## 1. Smart Metering Data

- Electricity meters
  - Reporting remotely: 30 min to 6 hour intervals
- Water Meters
  - Mostly reporting remotely: 6 hourly intervals mostly

## 2. Apartment Panel Survey

- June – August (wave 1), n = 131 complete responses
- September-October (wave 2), n = 69 complete responses

	Non-EDGE	EDGE
Cape Town	40	63
Johannesburg	7	23
eThekweni & Ballito	0	20
Total	47	106

## 3. Hot Water Nodes and Air Quality Sensors

- Report on Hot Water production
- Assess if Indoor Air Temperature and CO2 can be assessed

# Study Areas

## Cape Town



## Gauteng



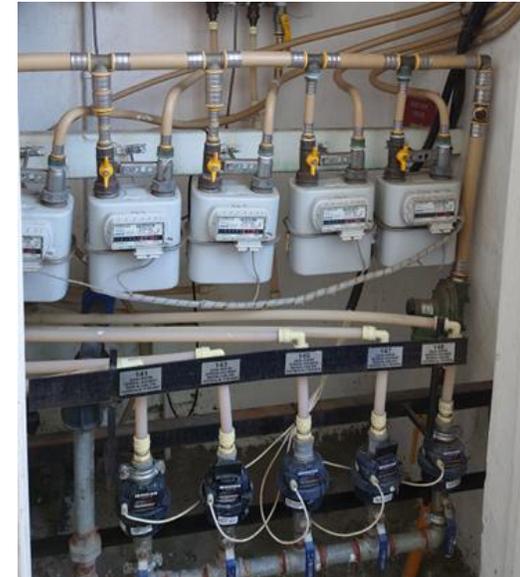
## eThekweni (Durban)



Cape Town, Johannesburg and Durban were selected as the main study areas due to the number of EDGE buildings in these municipalities and weather variance.

# Smart Meters

- Most pilot phase properties have smart electricity and water meters
- Data collected by metering companies on behalf of sites
  - No central system: metering solution companies appointed by the site developers or relevant municipalities
  - Separate arrangements required for each company
  - Data received in different formats
- Cumulative readings
- Variable granularity – minutes to (occasionally) days, sometimes varying between readings for the same meter
- 99+% of readings considered valid
- Some sites only have manually read meters – these have payment information available
  - Included to check feasibility of including non-smart metered sites
- E-Wallets
  - Tenants load balance
  - Energy and Water consumption billed against this prepaid balance until the balance goes to zero
    - If zero balance water still flows, but at restricted rate equivalent to 6kl per month

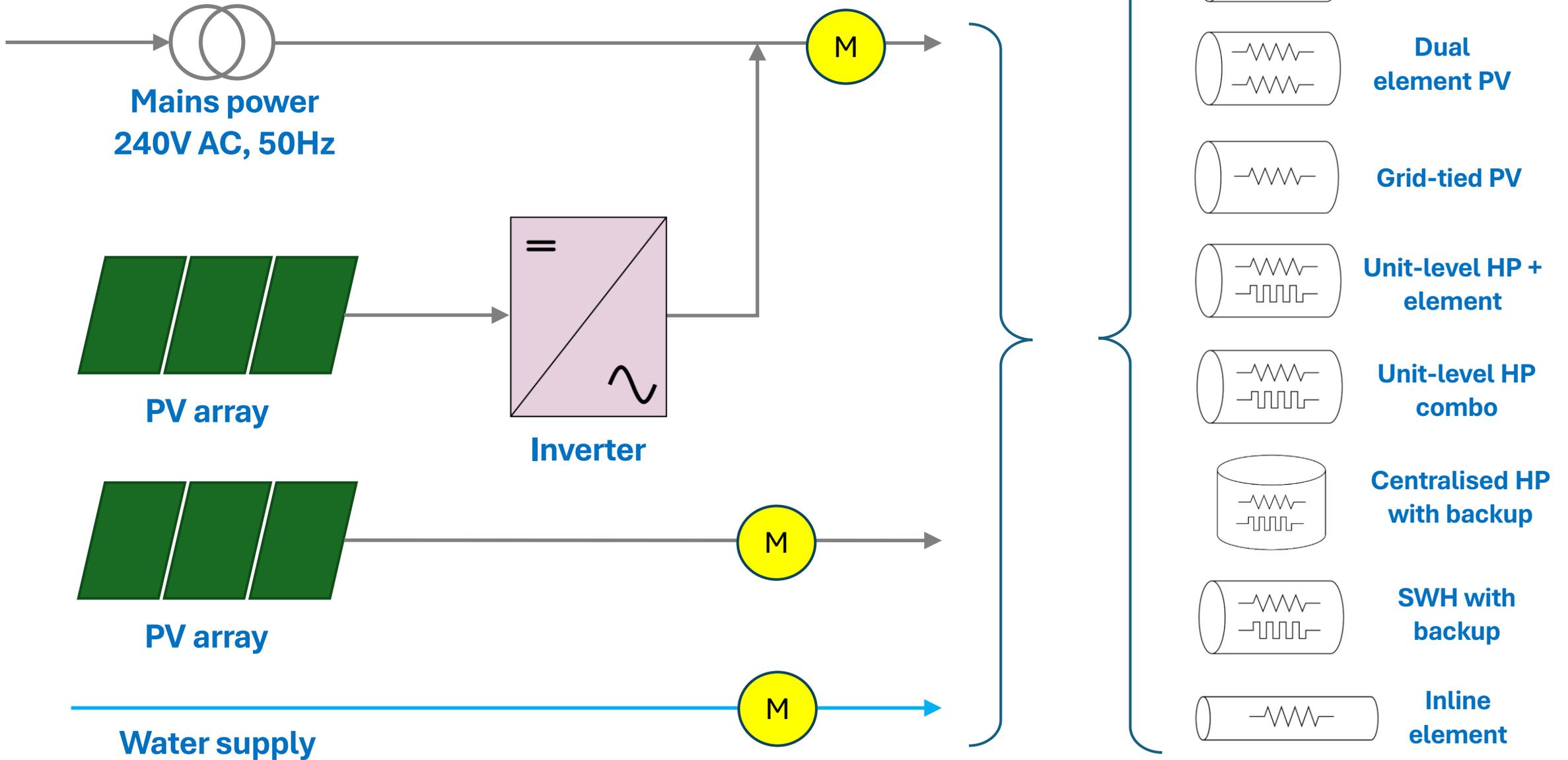


# Domestic Hot Water

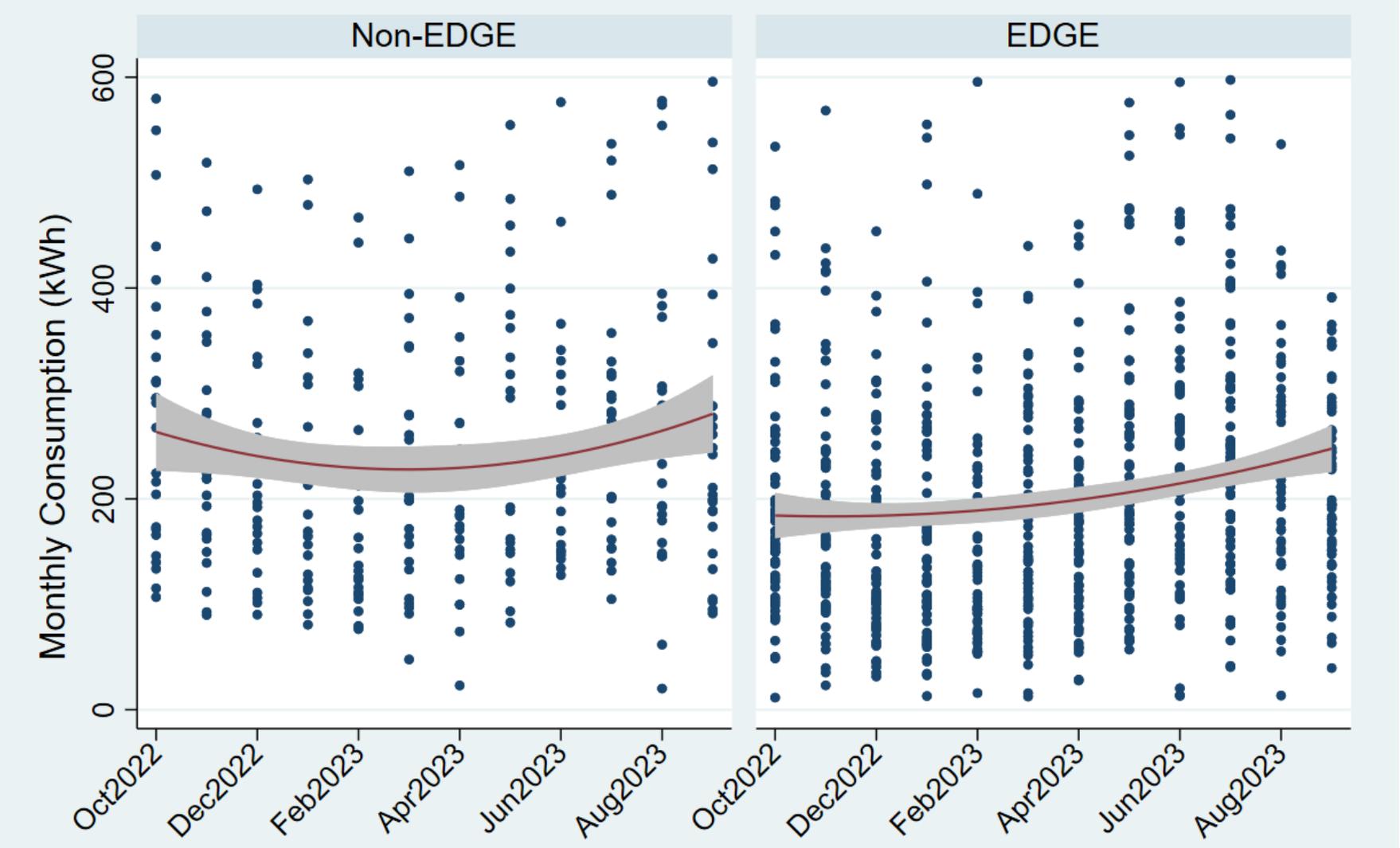
- Important
  - Local Building Standard and EDGE assume majority of base case apartment's grid energy used here
- Challenging to monitor:
  - Multiple water heating technologies and configurations
  - Periods without power – load shedding, user disconnections
- We also needed to consider:
  - Comms – to transmit data from the monitoring kit – metal, concrete
  - Location of the hot water geyser/tank/system – within units or in geyser cupboards in communal hallways etc. Constrained space for installation.



# Domestic Hot Water systems at Pilot Sites



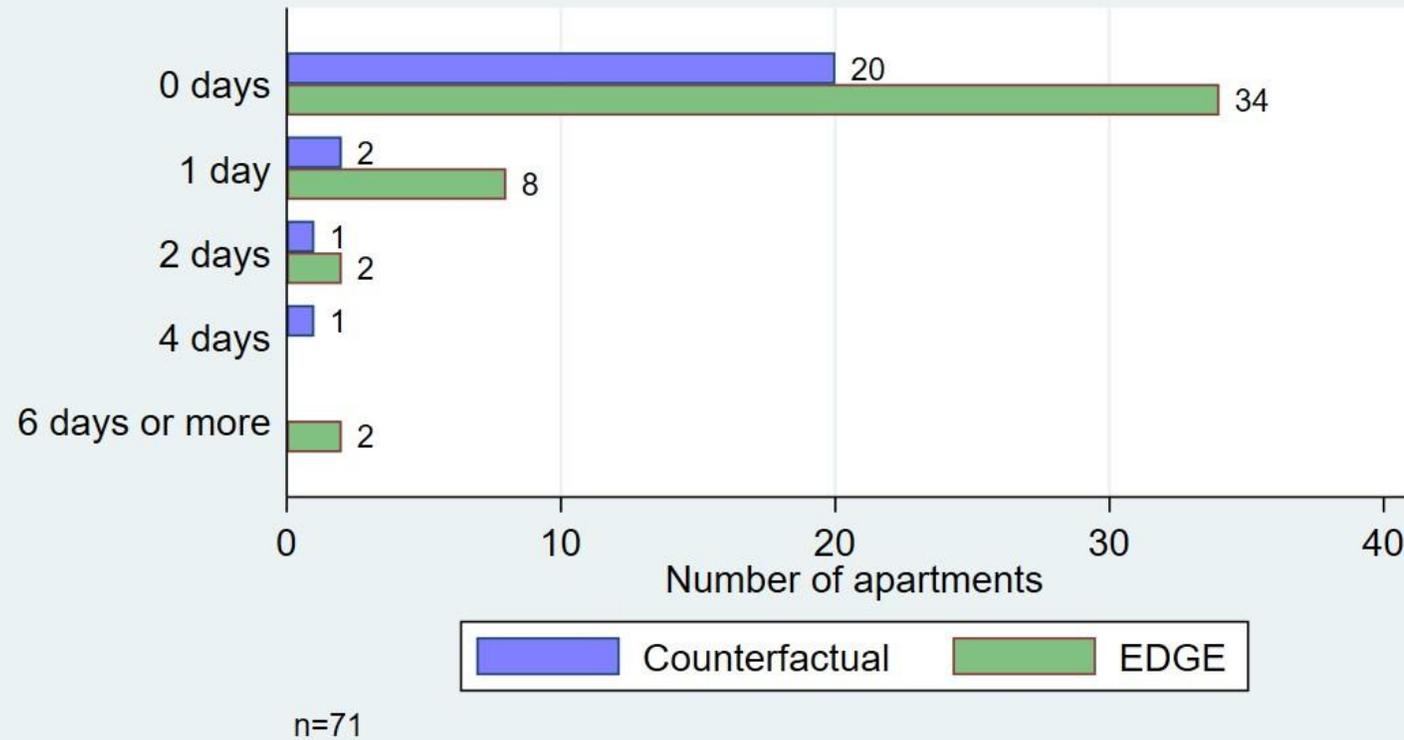
# Monthly kWh consumption (Quadratic fit with 95% CI's)



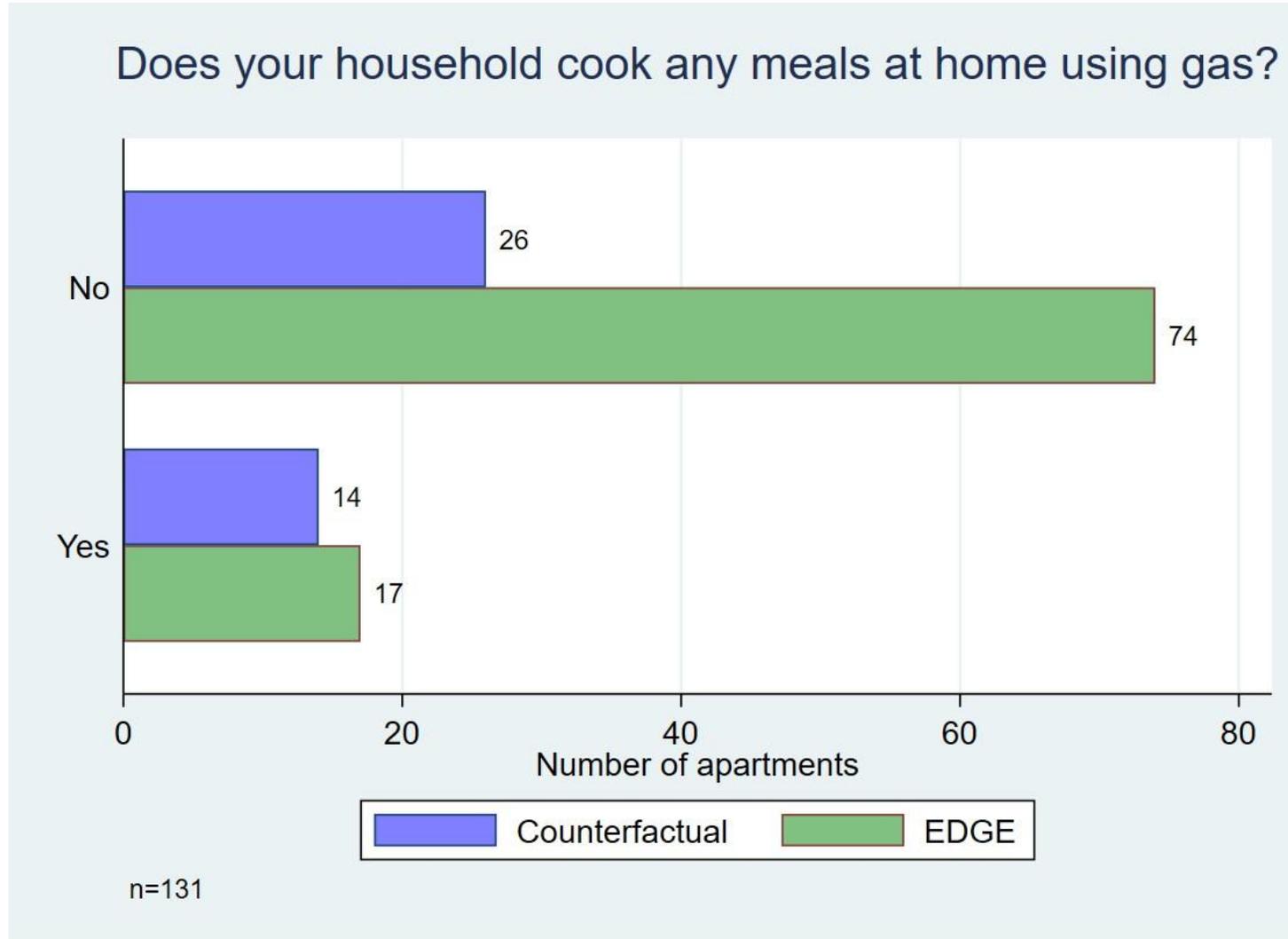
Very Small Sample – but suggestive of EDGE effect being present.

## Severe affordability constraints may affect a meaningful minority in the Main Phase

In the last 30 days how many days has your household gone without electricity because you could not afford to top up your e-Wallet or prepaid meter?



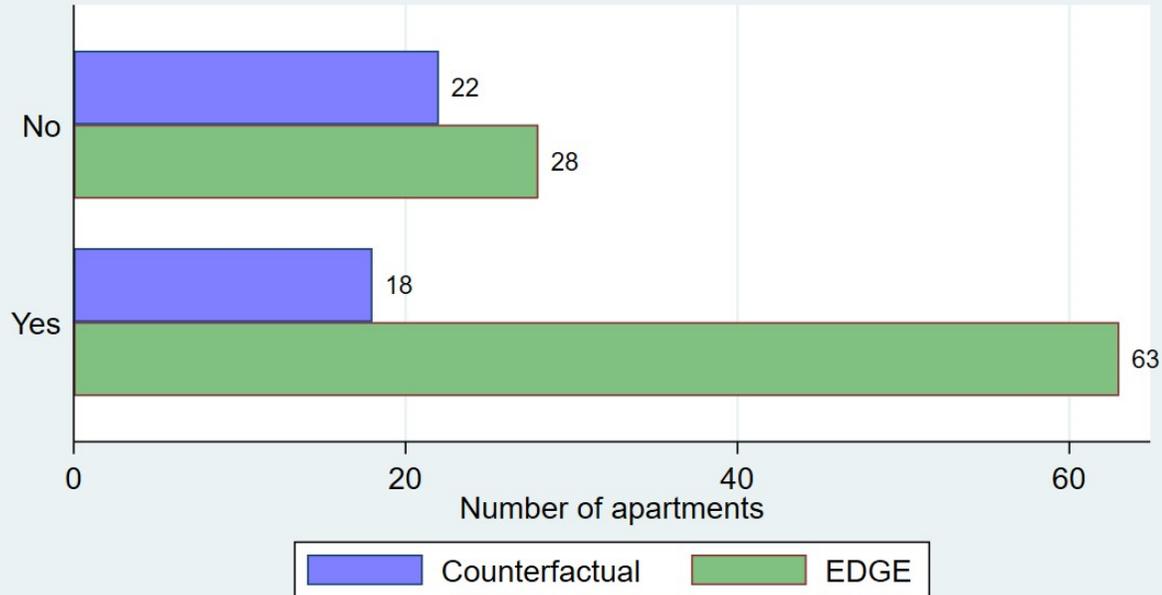
A meaningful number of households in the Main Phase are likely to cook with otherwise un-metered gas



## Behavioural Gaps may drive some over/under consumption in the Main Phase

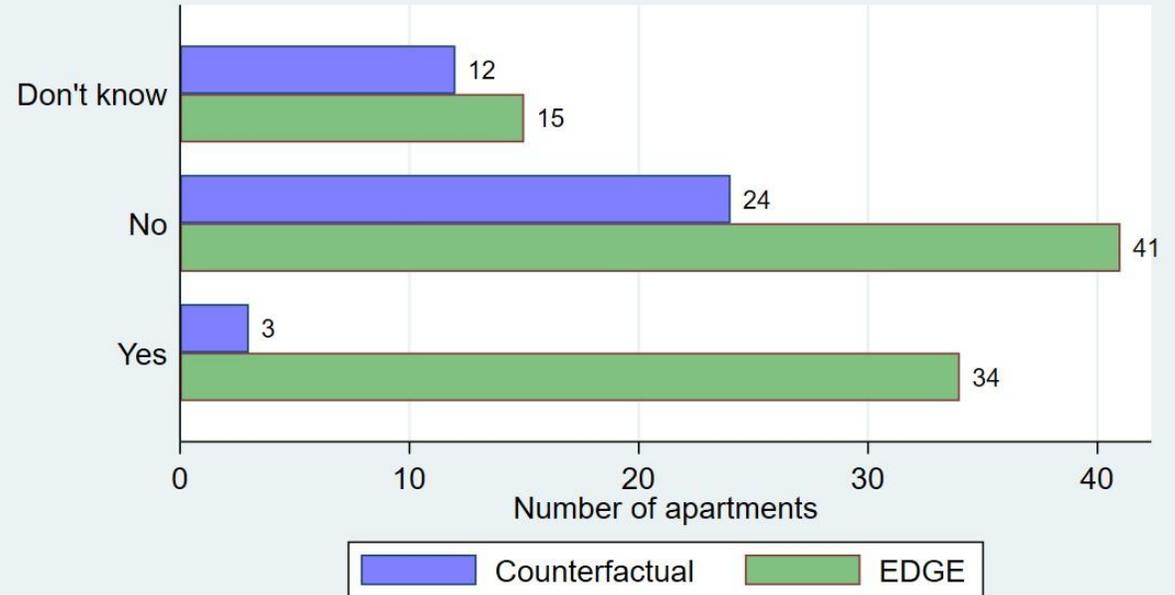
- Quite a few EDGE households in the pilot do not use the technology provided
- In some cases this resulted in the PV to geyser systems being switched off for a month or more...

Do you or anyone else in your household sometimes control your geyser from a display on your wall?



n=131

Do you or anyone else in your household sometimes control your geyser from an app on one of your phones?



n=129

# Insights from Pilot Study

## 1. Smart meter data

- Readily Available, at high fidelity
- Available at Scale with relative ease
- Ideal as a Big Data Backbone of Main Phase
- Start with Metering Firms to build out Main Phase
- AVOID non-smart metering
  - Low fidelity data
  - Apartments also tend to be older than appropriate proxy for EDGE “base case”

## 2. Household Survey

- Getting responses (recruitment)
  - Door invites (under door or on door) important element to increasing participation
  - Building managers to understand and advocate for survey important for awareness and trust
  - General communication from Developer important for trust
- Online Survey feasible at scale
- Apart from helpful data on households behind the meter
  - Indications of severe affordability constraints in populations not normally considered vulnerable
  - Indications of behavioural/understanding constraints

## Insights from Pilot Study (continued)

### 3. Additional Sensors

- Variability in type of hot water systems imposes significant burden on design
- Necessity of
  - Bench Test
  - Field Test
  - Then Roll Out
- Scale demands specialised firm (not a university)
- Data demands University (not a firm)

Main Phase

## Main Phase

### Research Questions

1. To what extent do EDGE-certified residential buildings deliver actual water (m<sup>3</sup>), and grid energy (kWh) savings compared with
  - a. EDGE model predictions and
  - b. Residential apartments built according to the South African building standard (SANS 10 400 XA / XA2)
2. To what extent do water and grid energy savings vary, and what drives this?
3. What can be done to increase the accuracy of predicted savings?
4. What can be done to increase actual savings?

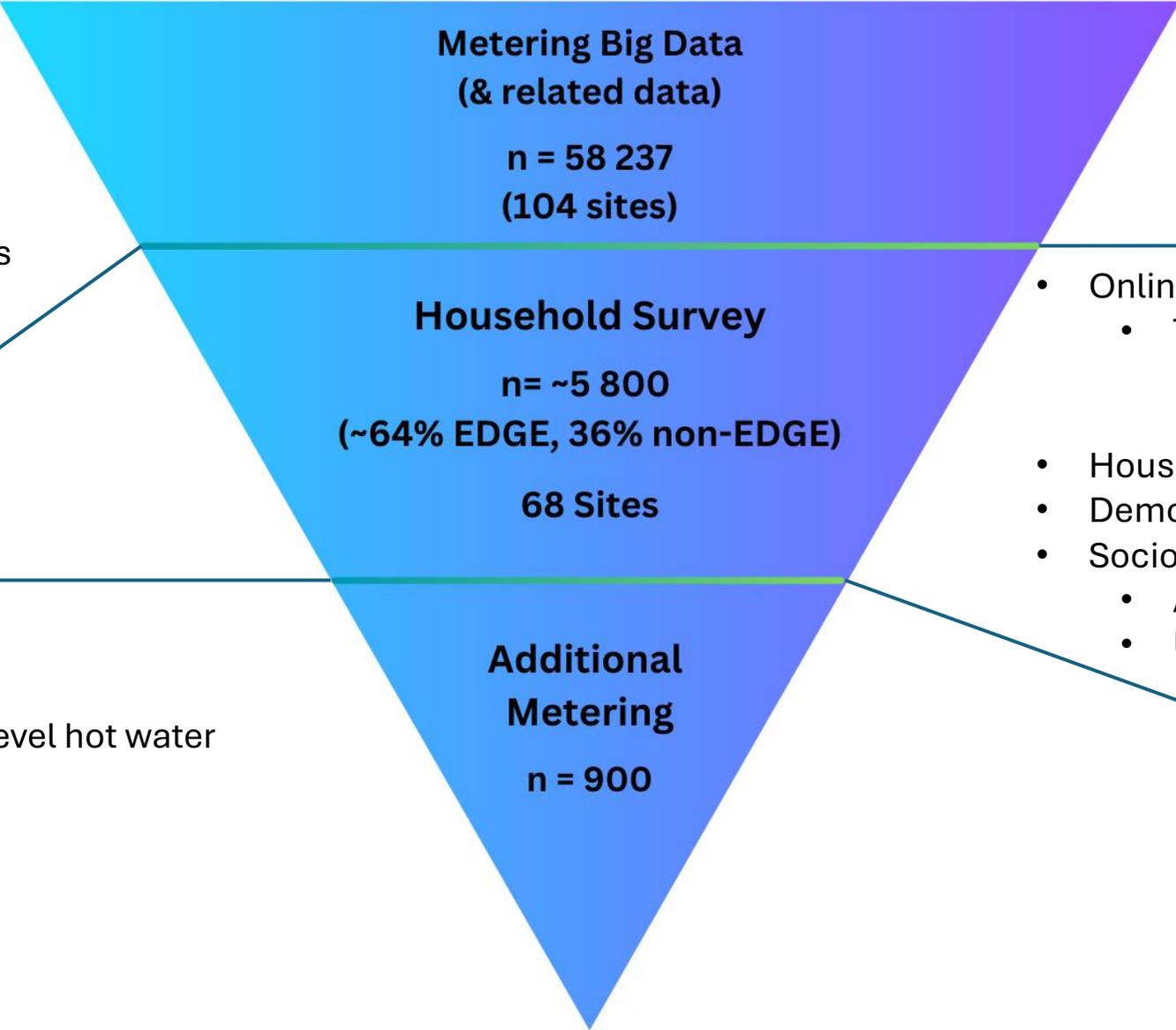
## Main Phase

### Steps of Setup

1. Secure additional Developer partners (since sample size needs to be larger)
  - There are 9 partners who have agreed to participate (up from 2 in the pilot)
  - Cape Town, Gauteng, eThekweni primarily, & a wide range of socioeconomic bands
  
2. Visit sample of Developer sites to assess for viability
  
3. Sign formal Data Sharing Agreements (DSA's)
  - Required in order to comply with South African Data Protection Laws
  - Develop Data Sharing Agreement template with UCT Legal department
  - Manage Developer attention to process the DSA
  - We have 7 out of 9 DSA's signed
    - Remaining 2 expected soon
    - More can be added
  
3. Secure Sufficient Computing and Storage Resources
  - There will be A LOT of data
  - High Performance Computing Cluster at University of Cape Town
    - Compute space and storage secured

# Main Phase Study Design: Data

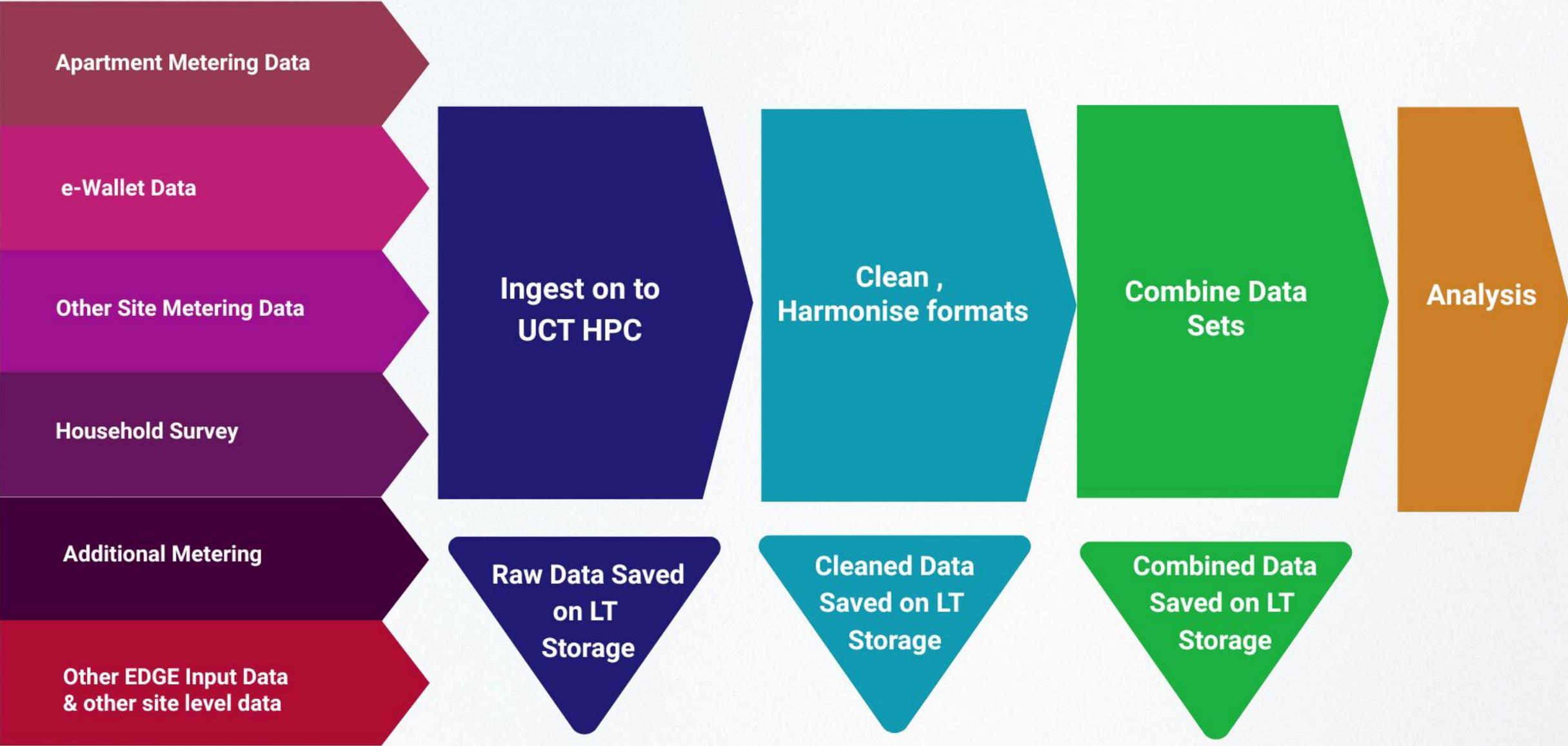
- Intraday reporting: 30min (mostly) to 6 hourly
- Grid Energy and Water (all sites)
- Hot Water (sizeable minority of sites)
- Payment events and e-Wallet balances (most sites)
- Other Service Metering (e.g. bulk hot water system components)



- Online Survey
  - Two waves
    - mid 2025,
    - mid 2026
- Household Characteristics
- Demographics
- Socioeconomic markers
  - Appliance Stock
  - Use Behaviour

- Recruited from Surveyed population
- Hot Water Production in apartment level hot water heaters (geysers)
  - Energy Used
  - Water Used
- Indoor Air Temperature & Humidity
- Apartment level gas bottle use

# Main Phase Study Design: Data Flow



Thank You



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# Edge Cert. Impact Evaluation Colombia

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**miyamoto.**

# EDGE Certification Impact Evaluations(Smart Metering Studies)-COLOMBIA



+



+



**Miyamoto Int.**

**DataPlus**

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*PROJECT COORDINATOR*

**ALEJANDRO SIMBAQUEVA**  
*SURVEY EXPERT AND DATA  
ANALYST*

**FABIO ANDRES TOCASUCHE**  
*DATA PROCESSING MANAGER*

- 1. Particularities of Colombian housing production**
- 2. Protocols + Lessons learned**
- 3. Voices from developers: Conaltura**
- 4. Next Steps**

# Project objectives

The project will conduct an assessment of the performance of existing EDGE-certified residential buildings in Colombia.

- Assess the actual energy savings achieved by EDGE-certified projects compared to conventional-non certified projects (comparison group)
- Review the performance of EDGE's energy savings prediction algorithm by comparing the predicted energy consumption results with actual on-site measurements in EDGE-certified buildings

# WHAT IS BEING PRODUCED?



Project value	Area	Category
90 MLW	Area: 40 - 48 m2	VIP
135 MLW	Area: 40 - 48 m2	VIS
175 MLW	Area: 60 m2	VIS RU
VARIES	Area 18-34 m2	Housing Solutions
VARIES	VARIES	Market

1 MLW = 340 USD

MLW: Minimum legal wage

VIS: Socia housing  
VIP: PRIORITY Social Housing

## HOW IS IT BEING PRODUCED?

- PPPs + private initiatives
- Based on POT regulations (city based)  
+ MinVivienda
- Self built (Autoconstrucción)

INFORMAL/  
SELF BUILT

60% +



# WHO MANAGES BUILDINGS?

- Horizontal Property: Building management companies/individuals (ADMISTRADOR)
- Supervised by: Owner Councils
- Regulated by: 675/ 2001-without supervision-it's only mandatory for comercial.

## ORGANIGRAMA DE UN CONJUNTO RESIDENCIAL



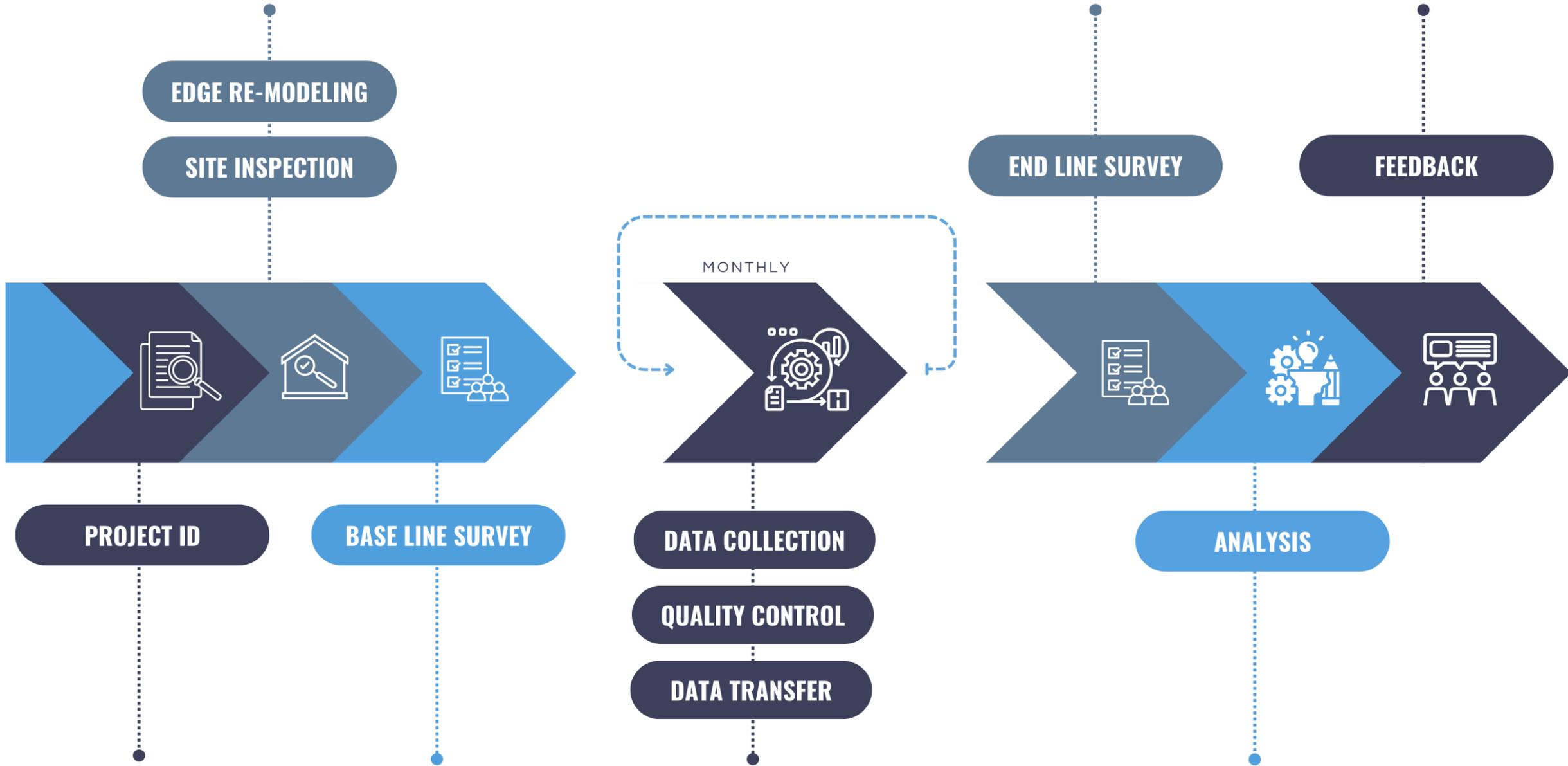
- **Most EDGE projects are VIS (aprox. 73%)**
- **Most VIS are high rise ( +6 stories)**
- **VIS projects are delivered with no finishes**

#### General insights of EDGE certified projects in Colombia (may 2024):

- More than 95% of EDGE certified projects in Colombia are certified under EDGE v2.1.5.
- Bogota, Cali, and Medellin represent more than 90% of EDGE certified projects. Bogota has 50% of the total.

#### Common features of EDGE certified projects

- Improved window to wall ration and solar shading
- Water efficient fixtures
- Efficient water heating systems
- LED lighting provided (common VIS/VIP do not include light appliances)



## PILOT PHASE SAMPLE

The pilot phase includes a subset of 100 housing units, selected from a shortlist of the EDGE-certified projects that had achieved EDGE final certification by the end of May 2024, provided by Camacol (the Colombian Chamber of Construction), EDGE's local partner in Colombia

### Variability of study sites

- Climate zone
- Building typology
- Housing type

### Selection criteria:

- Same location (city)
- Same Housing typology
- Same Utility tariff (strata)
- Same area and bedroom in units
- Same construction typology

THERMAL ZONE	ALTITUDE	CITY	COLPATRIA	BOLIVAR	MELENDEZ	CONALTURA	PRODESA	TOTAL PER CLIMATE ZONE
Cold	2600	Bogotá	1 pair			1 pair	1 pair	3 pairs
Temperate	1285	Ibague	2 pairs					2 pairs
Warm humid	0	Barranquilla	1 pair			1 pair		2 pairs
Temperate	1495	Medellin				2 pairs		2 pairs
Warm dry	1000	Cali		1 pair	3 pairs			4 pairs

## PROJECT ID

	Criterios DETERMINANTES (si o si debe cumplir)	Criterios CONDICIONANTES (no necesariamente debe cumplir)
Localización	Misma ciudad	Mismo plan parcial
Características socioeconómicas	VIS /No Vis	Estrato
Características de las unidades	Misma área de las unidades de vivienda	Área comparable pero misma cantidad de habitaciones
Características tipológicas de la edificación	Misma tipología: Casa / Edificación en altura	Misma altura de la edificación
Características constructivas	Mismo sistema constructivo	Mismos acabados

- ✓ **Study Partners (developers) have been key for project ID and secure access to building**
- ✓ **A "pairing" strategy was used and maintained throughout the Project ID phase.**

- ✓ **Need for project replacement protocol.**

✓ Site inspection is key to building lasting relationships with building administrators.

EDGE RE-MODELING

SITE INSPECTION

CUARZO CODIGO DE PROYECTO							STATUS	
							SECURED ACCESS	
LOCATION	CALI	EDGE CERTIFIED	X	NON-EDGE CERTIFIED	# OF TOWERS	4	STORIES PER TOWER	12
ADDRESS	Carrera 101B # 50 - 228	DEVELOPER	MELENDEZ		TOTAL # UNITS	384	BRM PER UNIT	2
		NOTES					STRATA	4
01	BUILDING EXTERIOR DOCUMENTATION			Notes: cuentan con fuente de energia solar.				
								

03	ELECTRIC SUPPLY METERS (LOCATION)	
Notes: Se encuentran en la parte externa de cada torre.		
		
04	GAS SUPPLY METERS (LOCATION)	
Notes: Se encuentran en la parte externa de cada torre.		
		
05	WATER SUPPLY METERS (LOCATION)	
Notes: Se encuentran en la parte externa de cada torre.		
		

## BASE LINE SURVEY

- ✓ Need to shorten survey to avoid participant desertion
- ✓ Need to include participant recruitment for special monitoring
- ✓ Need to adjust incentives to include building administrators

## DATA COLLECTION

## QUALITY CONTROL

## DATA TRANSFER

- Quality control measures still being tested

- ✓ Needed to understand potential changes in consumption
- ✓ Not piloted

## END LINE SURVEY

# Additional monitoring equipment

## *Main Challenges Identified*

**Location:** Some building administrators do not allow installation of monitoring equipment in meter rooms and sometimes are only accessible for Utility's staff.

**Community Engagement:** Lack of trust has made participant recruitment difficult.

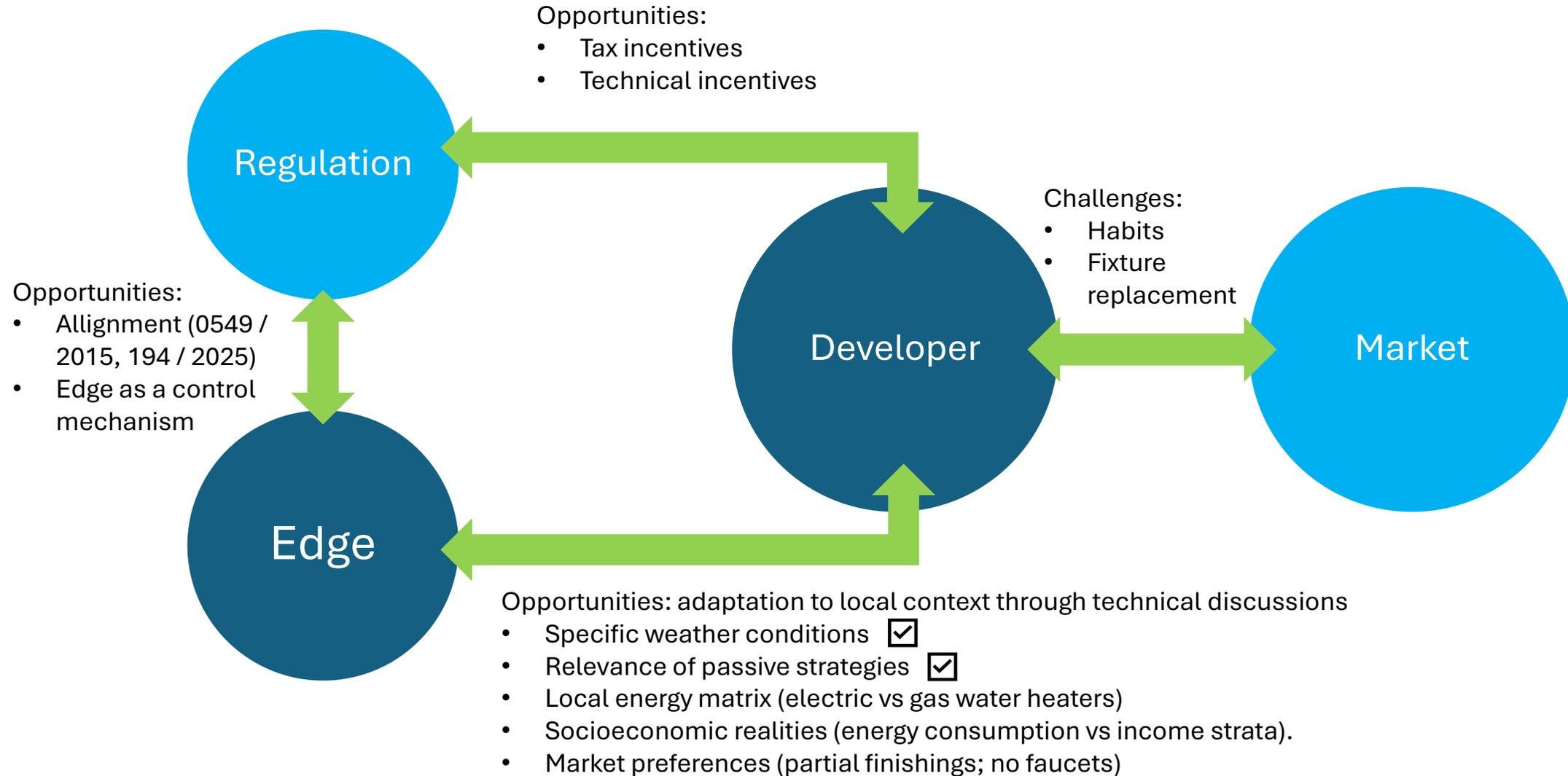
**Installation:** Monitoring devices require stable wall anchoring. Vendors should anticipate wall repair needs post-study. If installation is required in each apartment, this could present logistical challenges and could require between 30-60 minutes per apartment.

**Wi-Fi Signal for Data Transmission:** Since some monitoring devices will be installed inside homes, setting up a separate network for each device could be costly.

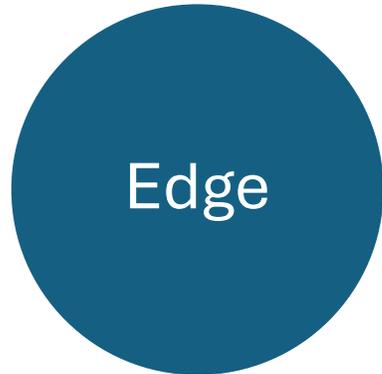
**Access to information:** Energy consumption readings should not be available for the participants to avoid any possible interference in the behavior. A report will be provided at the end of the study.

**Energy consumption profile:** Smart meters could provide insights on energy consumption by heavy home appliances (oven, fridge, water heater, etc.) but this could lead to changes in behavior as this feature requires active engagement from the residents to configure the devices.

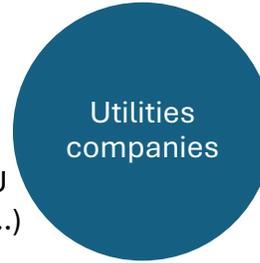
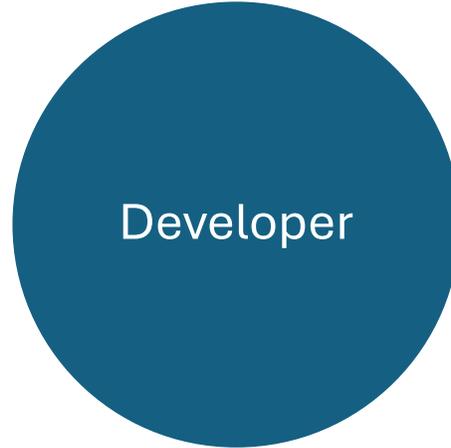
# IMPROVING THE SYSTEM



# KEY STAKEHOLDERS WITHIN THE SYSTEM

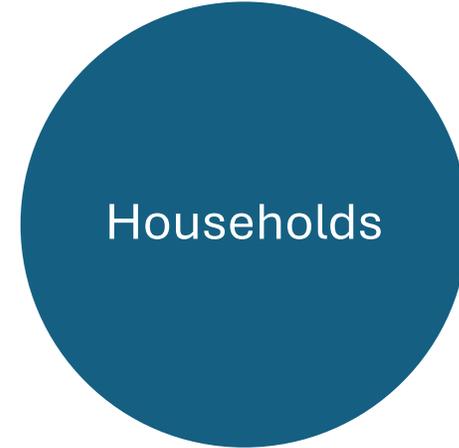


- Challenges:
- Efficiency vs. design (trends)
  - Efficiency vs. Comfort
  - EPD (embedded carbon)
  - Technical specifications (U value, light transmittance...)



- Challenges:
- Access to consumption data
  - Efficient resource use by users
  - Market shift towards electrification
  - Decarbonizing the energy mix

- Opportunities:
- Smart meters
  - Energy communities



- Challenges:
- Calculating economical impact of financial incentives
  - Technical incentives

- Opportunities:
- Financial incentives
  - Alternatives to loans

- **Finalizing piloting additional monitoring equipment**
- **Incentive definition**
- **Site Inspection and participant recruitment**
- **Data Collection targeted to start July 10**

# miyamoto.

conaltura

Somos ▶

Empresa



Certificada



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# MAGC Research Indonesia

*EDGE is an innovation of IFC, a member of the World Bank Group.*

# Indonesia Household Context

## Electricity

- PLN is the sole distributor of electricity (state-owned company)
- Indonesia classifies home electricity connections by the size of the main breaker, that sets a ceiling on number of connected appliances (wattage) at once.
- Electricity generation is dominated by coal (58%), followed by natural gas (27%), renewables (8%), and oil (6%).

Class	Rate per kWh	USD	Percentage of households
R-1/450 VA	Rp 415	\$0.0268	32.8%
R-1/900 VA	Rp 586	\$0.0378	16.3%
<b>R-1/900 VA-RTM</b>	<b>Rp 1352</b>	<b>\$0.0872</b>	<b>35.5%</b>
R-1/1300 VA	Rp 1467,28	\$0.0947	14.1%
R-1/2200 VA	Rp 1467,28	\$0.0947	1.2%
R-2/3500 VA, 4400 VA, 5500 VA	Rp 1467,28	\$0.0947	0.1%
R-3/6600 VA and above	Rp 1467,28	\$0.0947	0.0%

## Water

Water provision in Indonesian residential developments comes through three main systems (non-consumables):

- Groundwater Extraction (unmetered)
- Private Water Treatment Plants
- **Municipal Water Services (PDAM/PAM)**

## Gas Supply (Cooking)

Gas is distributed through bottled **liquefied petroleum gas (LPG)**, organized by sizes:

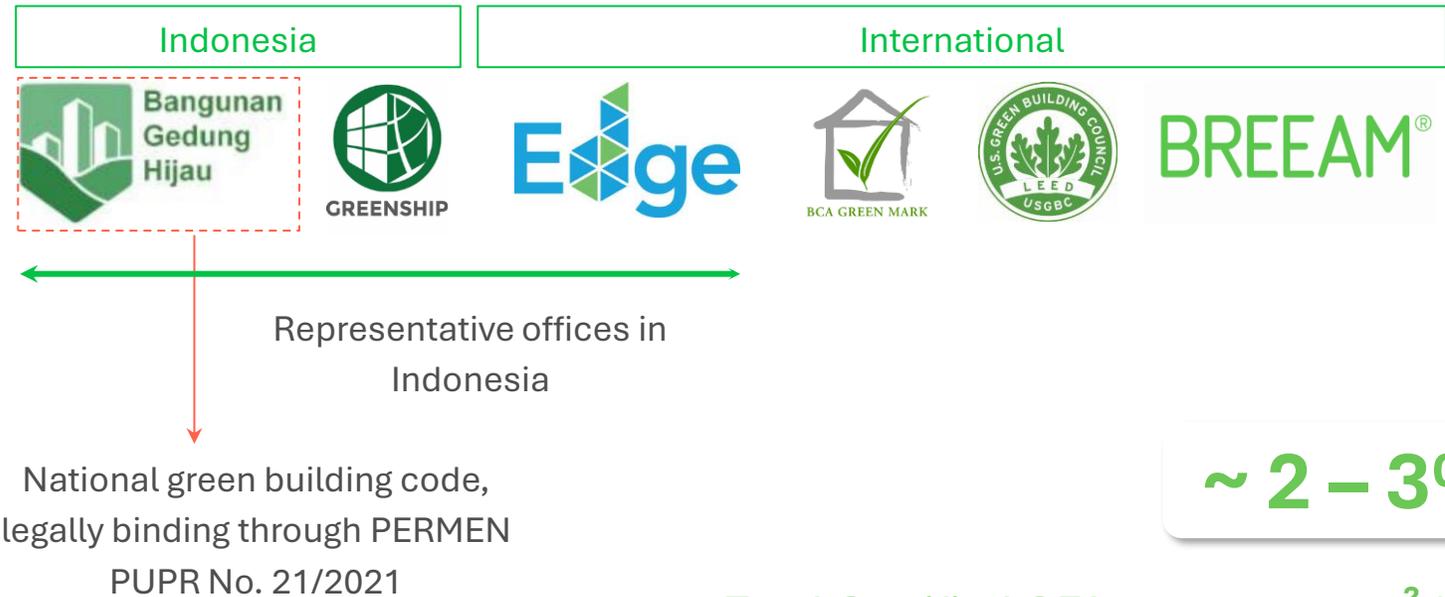
Size	Colour / brand	Typical user segment
<b>3 kg</b>	Green	Low-income homes
<b>5.5 kg</b>	Pink "Bright Gas"	Young families, apartments; middle-class
<b>12 kg</b>	Pink "Bright Gas" (replacing old blue)	Established middle-class homes and above

# State of Green Building in Indonesia

## Green Building Certification

- Green building certification in Indonesia started since 2011.
- EDGE marked its presence in 2014.
- To date, around 14.6 million of sqm floor area of buildings have been certified.

Green building certification that has been used in Indonesia:



~ 2 – 3%

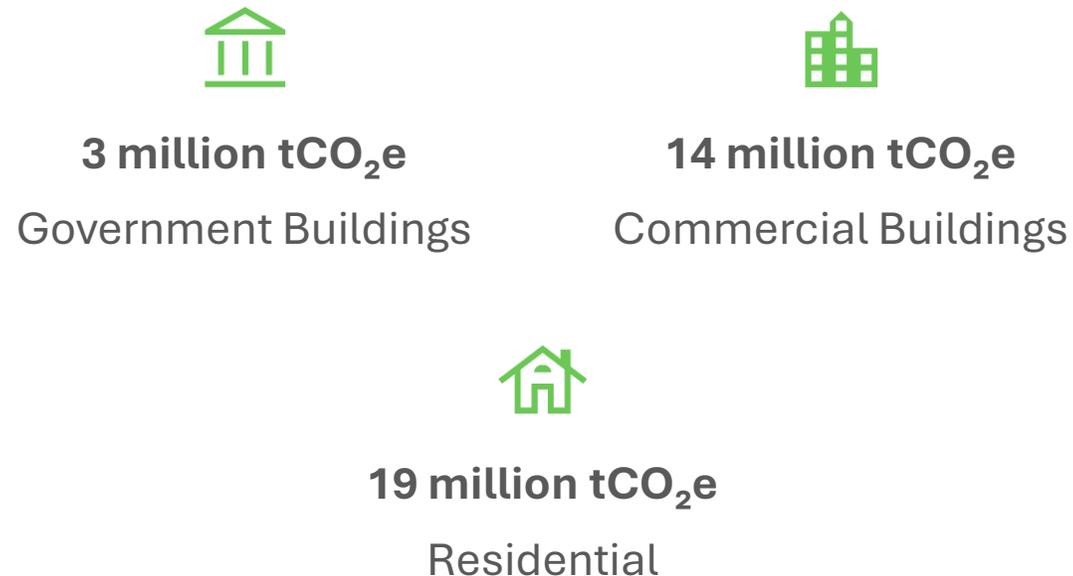
Total Certified GFA 14,654,613 m<sup>2</sup> (2024)

Certification	Greenship	SBGH	EDGE	LEED	BCA Green Mark	BREEAM
Projects	>146	~ 31	140	43	21	2
Gross Floor Area (GFA)	>8,746,813 m <sup>2</sup>	545,728.57 m <sup>2</sup>	2,893,642 m <sup>2</sup>	1,238,147 m <sup>2</sup>	± 1,106,282 m <sup>2</sup>	124,000 m <sup>2</sup>
Active Since	2011	2015	2014	2011	2011	2016

# State of Green Building in Indonesia

## Roadmap

Indonesia has laid out its roadmap in 2023, by 2030 to achieve following carbon emission reduction:



## Energy Efficiency

Other than green building certification, Indonesia also enforces Minimum Energy Performance Standards (MEPS) with rating based system on following appliances:

- AC ✳
- Refrigerator 📺
- Rice Cooker 🍚
- Fan 🌀
- LED light 💡
- Television 📺
- Water Dispenser 🚰
- Refrigerated Display Case 📺

# EDGE Certified Buildings in Indonesia

## Distribution

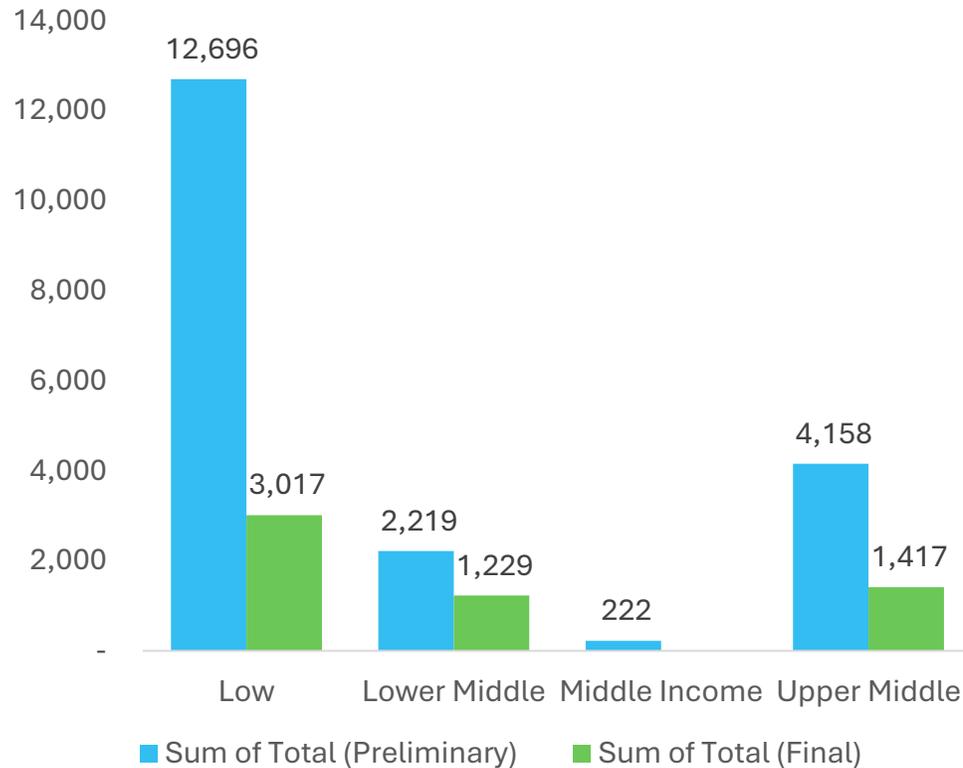
Location	Preliminary	Final
Bandung	1,801	-
Batam	-	44
Bekasi	-	19
Denpasar	1	-
Jakarta	11,819	2,750
Lebak	554	373
Makassar	291	120
Palembang	2,792	2,357
Tangerang	55	-
Semarang	1,982	-
<b>Grand Total</b>	<b>19,295</b>	<b>5,663</b>



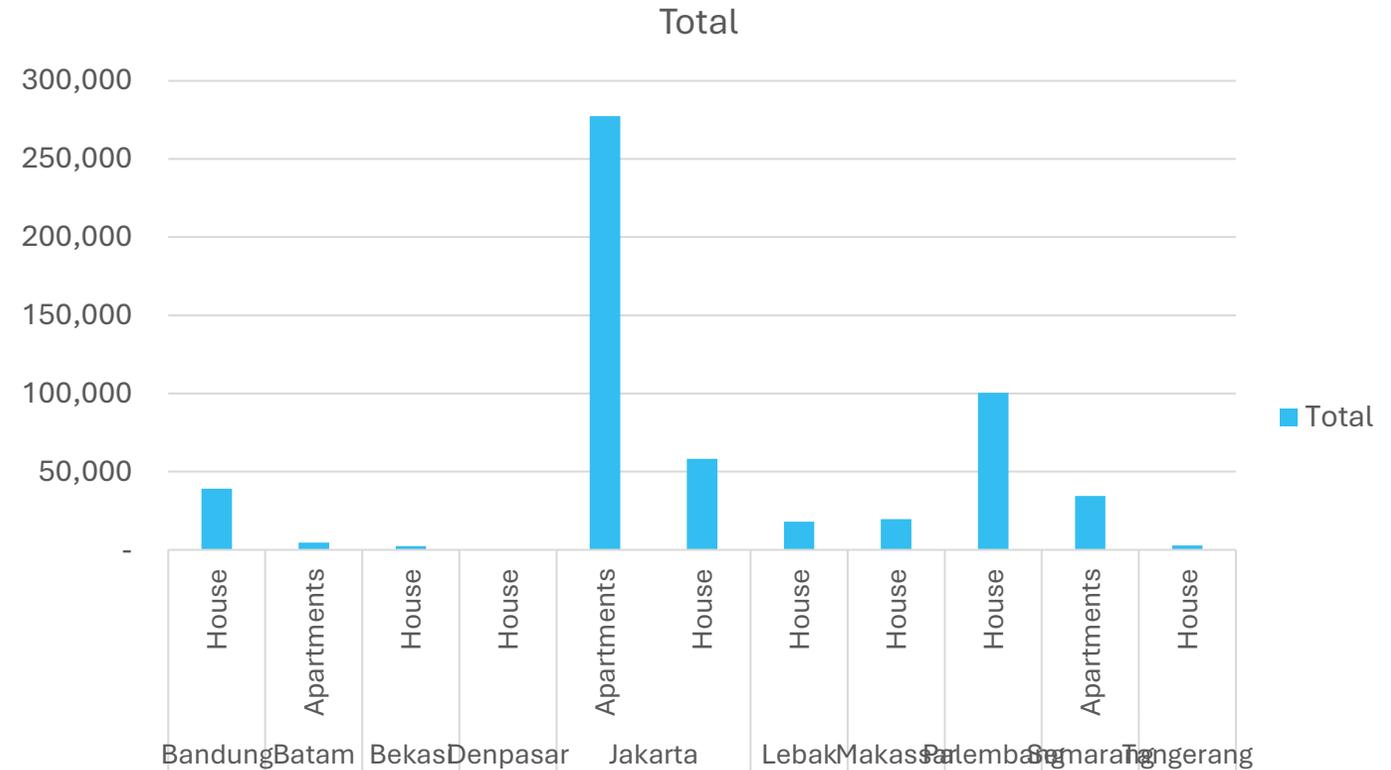
*EDGE projects are mostly located within the Jakarta Metropolitan Area (Jakarta, Bogor, Depok, Tangerang, and Bekasi). Jakarta Metropolitan Area—encompassing Jakarta, Bogor, Depok, Tangerang, and Bekasi—12,447 units representing **64.5%** of all EDGE-certified developments in Indonesia.*

# EDGE Certified Buildings in Indonesia

## Socioeconomic Income Level



*Based on the number of certified units, most projects are within low income brackets. This is followed by upper middle and lower middle. This classification follows income percentile.*



*Based on the floor area, Jakarta has the largest total floor area, dominated by apartment developments.*

# Snapshot of Our Study

## 1. Site Screening Results



Site screening for the study in Indonesia follows these steps:

1. Identifying population in Jakarta Metropolitan Area
2. Classification by income percentile (House-price-to-income ratio) and certification stage
3. Eligibility Assessment, excluding:
  - a. Temporary rental properties
  - b. Under construction
  - c. Projects with major changes departing from EDGE specifications
  - d. Estates that are unwilling to participate

 Landed housing

*Color code: green (low income);*

 Apartment

*orange (middle income); yellow (high income)*

# Methodology

## Types of Data

Data Type	Collection Method	Description
<b>Building Construction Data</b>	Refer to checklist prepared by the CRT	Systematic documentation of building materials, construction techniques, and implemented green measures (for EDGE-certified buildings).
<b>Energy and Water Consumption Data (Bill data)</b>	Manual meter reading and photograph of historical data	Historical utility bills and consumption records collected periodically on-site
<b>Household and demographic data</b>	Questionnaires	Self-reported information on energy and water usage patterns, demographic and occupant behaviour
<b>Environmental and High-Resolution Energy Data</b>	Smart sensors	Continuous monitoring of indoor environmental conditions and detailed energy consumption patterns over extended time periods

To get a holistic understanding of the energy and water consumption, we capture multiple types of data. Data type include building level data (required for EDGE simulation), down to low-res energy consumption (based on metering information), to behavior (using questionnaire), and finally high-resolution data from smart sensors.

Smart sensors are not commonly pre-installed in these house, so we asked consents from subsets of our sample to have their houses installed with smart monitoring equipment systems, which include:

- Temperature and humidity sensors
- Unit level energy monitoring
- Smart plug or appliances level energy monitoring
- PIR sensors (human presence)

*Types of data and corresponding collection method, by hierarchy of data collection*

# Energy Consumption Data

## Manual Meter Readings

### Energy Data (low res)

Low-res energy data captures longitudinal unit level energy consumption. Data is captured from electricity metering available at each residential unit.

Upon inspection, we encounter three types of metering:

- PLN Meter (prepaid/ token)
- Bank DKI Meters (prepaid/ token)
- Estate Managed Meters (postpaid)

### Prepaid/ token

You pay for electricity upfront by entering a purchased token code into the meter.

### Postpaid

You use electricity first and receive a monthly bill to pay afterward.

1

### PLN Meter

Standard energy meters used by majority of households. Majority use tokenized (top-up based) system. No smart monitoring available.

2

### Bank DKI Meters (Third Party)

Apartment buildings divide the billing to their occupants. In social housing or low income apartments, the billings are managed by third party. For instance, Bank DKI. Third party like Bank DKI has ability to manage the top up through their own mobile apps.

3

### Estate Managed Meter

Apartment buildings divide the billing to their occupants using their own meters. Without apps support, usually the billing was done by manual meter reading.

# Energy Consumption Data

## Manual Meter Readings



Token based system allows people to pay upfront. There are two ways to monitor the energy consumption in any token based system:

1. Retrieve the token purchase history (by using PLN consumer's ID)
2. Read the display manually

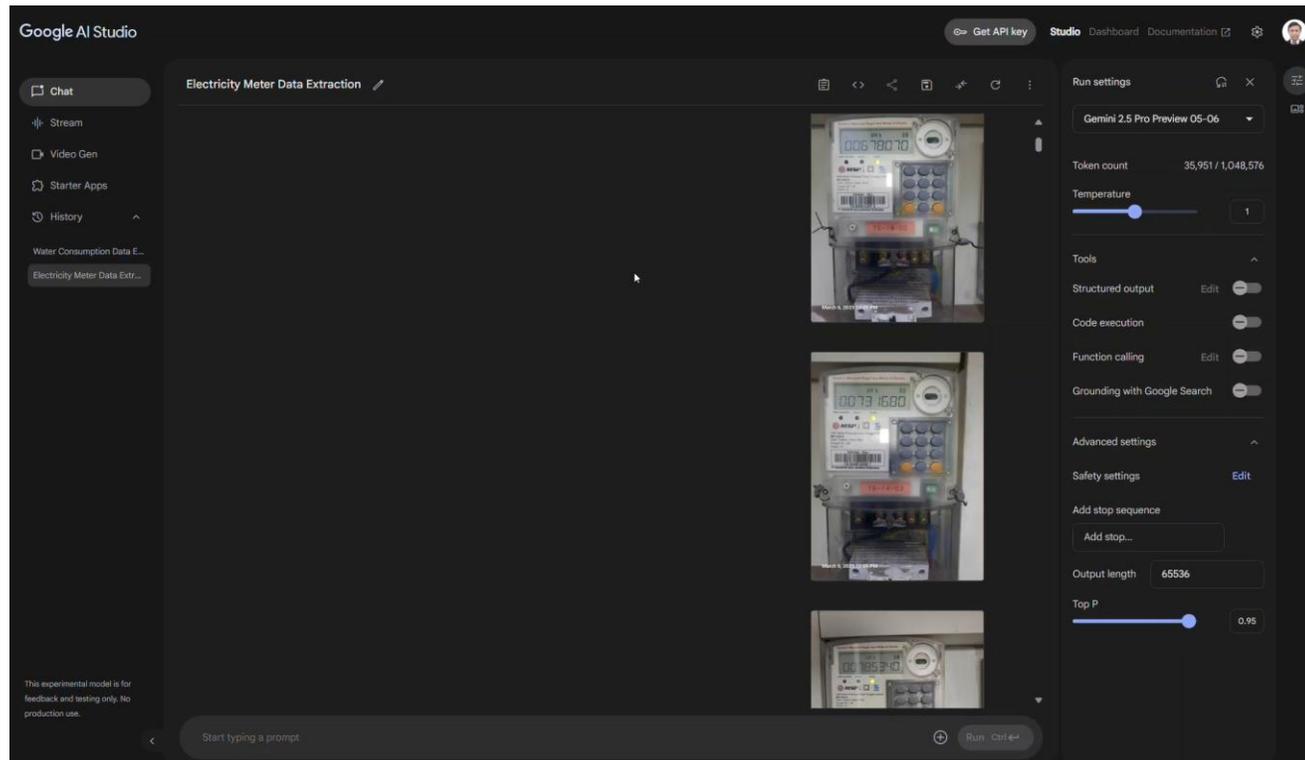
Token based system is not a smart meter although credits can be purchased through online banking or payment system

- Buy credit online or at a shop and get a one-time 20-digit token. The 20-digit token is precoded, act as a checksum
- The meter will check the combination. Certain combination will return the desired amount of credits.
- The meter then runs offline, subtracting kWh as you use power—no live link to PLN is needed.

Token value (IDR)	Token value (USD) *	Electricity credit (kWh)
50 000	3.02	33.6
100 000	6.04	67.2
200 000	12.08	134.4
250 000	15.10	168.0
500 000	30.20	336.0

*This table tells the top up amount (in IDR and USD) and the credited kWh. \*Based on the mid-market rate on 14 May 2025 (1 USD ≈ Rp 16 554).*

# Energy Consumption Data Using LLM for Data Extraction

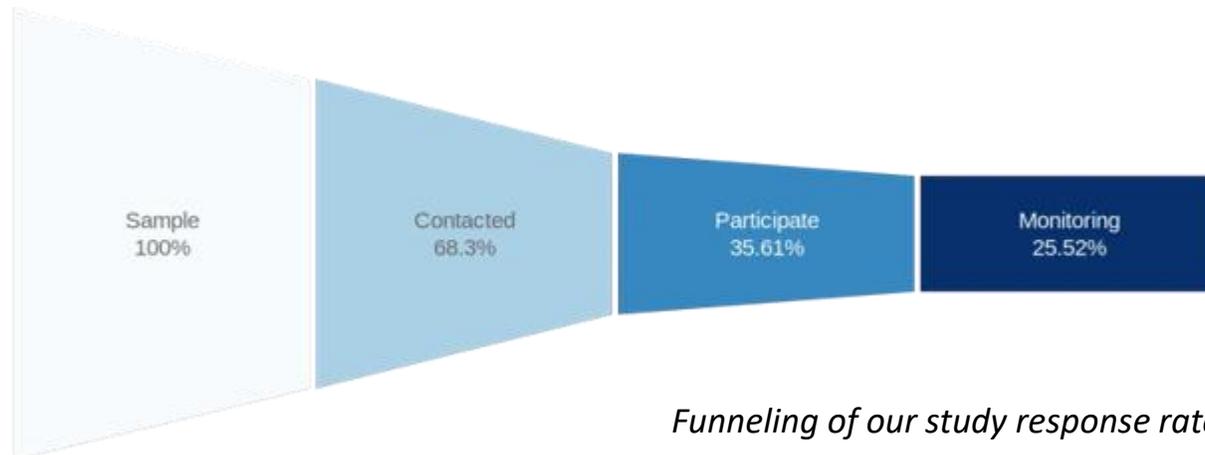


Retrieving data from PLN consumer's ID is more convenient as we can see the token topup history through the mobile app. However, if it is not possible, then manual meter reading is required. Manual meter readings works this way:

1. Research team members were pre-trained to take photos and readings procedurally using fieldwork protocol.
2. Our research team conducts manual on-site readings using specific "short codes" that retrieve up-to-date total energy usage information from these meters.
3. During regular site visits, we document meter readings through photographs. Photos should clearly show the display, meter number, and timestamp.
4. The photos are later processed through a LLM Model to generate time-series consumption data with corresponding dates in CSV format.
5. CSV data will be manually verified to see errors in image data reading.

# Household and Demographic Data Samples

Location	Total sample	Units contacted		Survey completed		Consent received for Monitoring systems	
		Number	%	Number	%	Number	%
EDGE Certified Project	216	100	46.3	70	32.4	49	22.7
Non-EDGE Certified Project	121	105	86.8	50	41.3	37	30.6

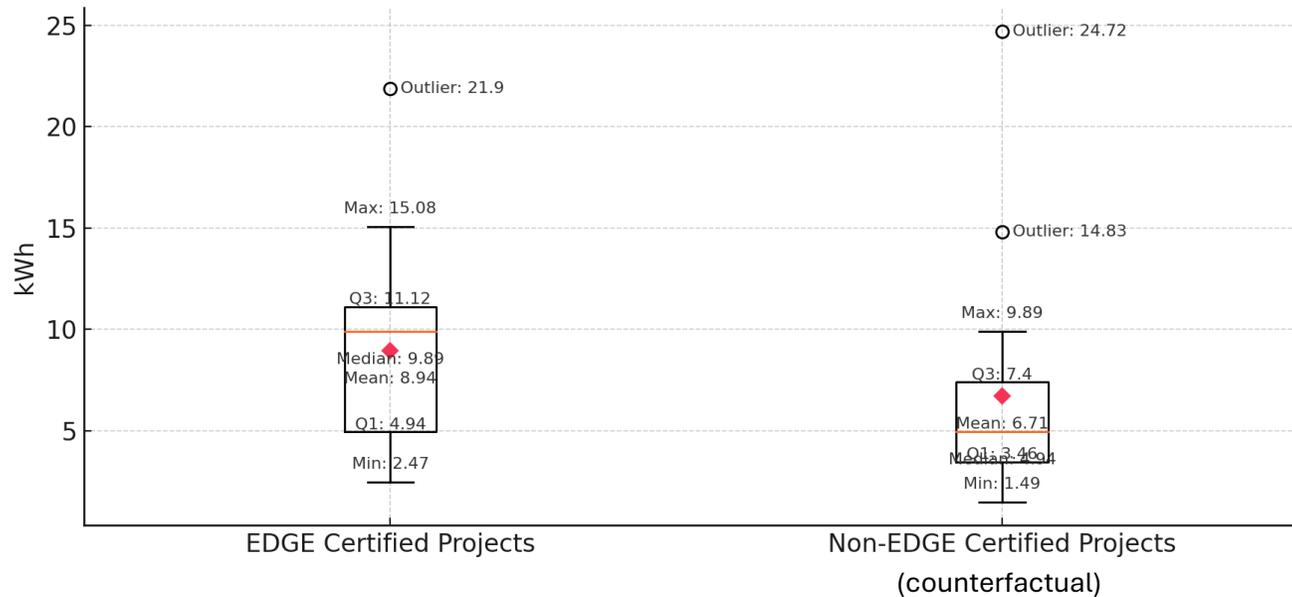


## Method:

- Using questionnaire to understand demographic and energy consumption pattern
- Face-to-face data collection returns higher response rate (35%) than online distributed questionnaire (1%)
- *Samples: number of units in that site*
- *Units contacted: number of units that respond during site visit*
- *Survey completed: households that consent to participate filling in the questionnaire*
- *Monitoring systems: consented households that are willing to participate in smart energy monitoring system installation*

# Pilot Phase Findings

## Energy Consumption Data

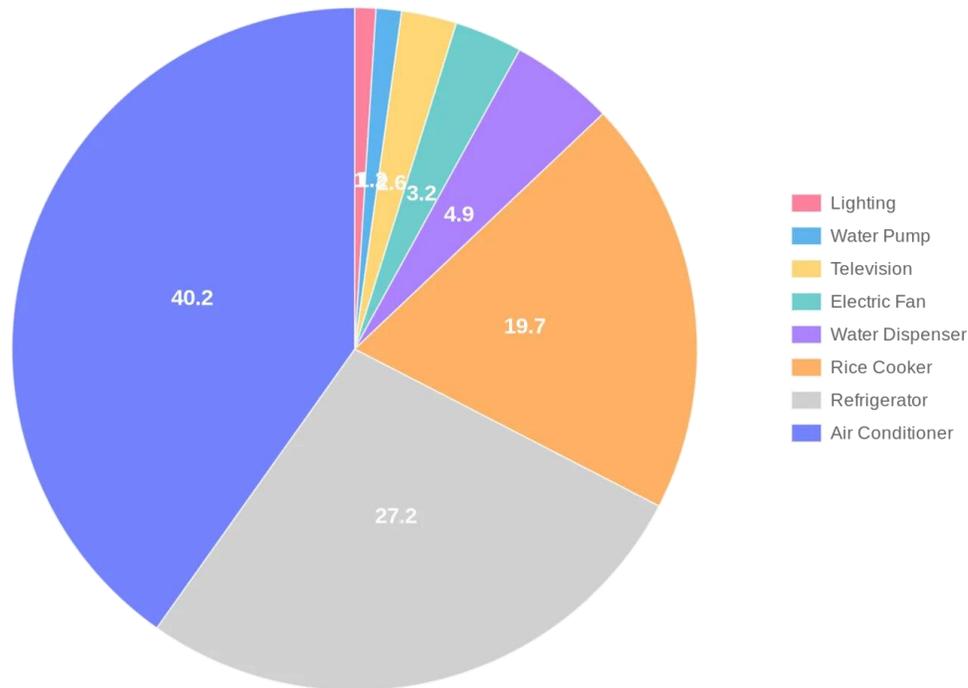


EDGE Certified Projects shows a wider spread of energy use, with a median of 9.89 kWh and an average of 8.94 kWh. The lowest recorded usage is 2.47 kWh, and the highest value within the whisker (non-outlier) is 15.08 kWh. One clear outlier is observed at 21.90 kWh, showing unusually high consumption in one unit. The standard deviation is 7.95.

# Pilot Phase Findings

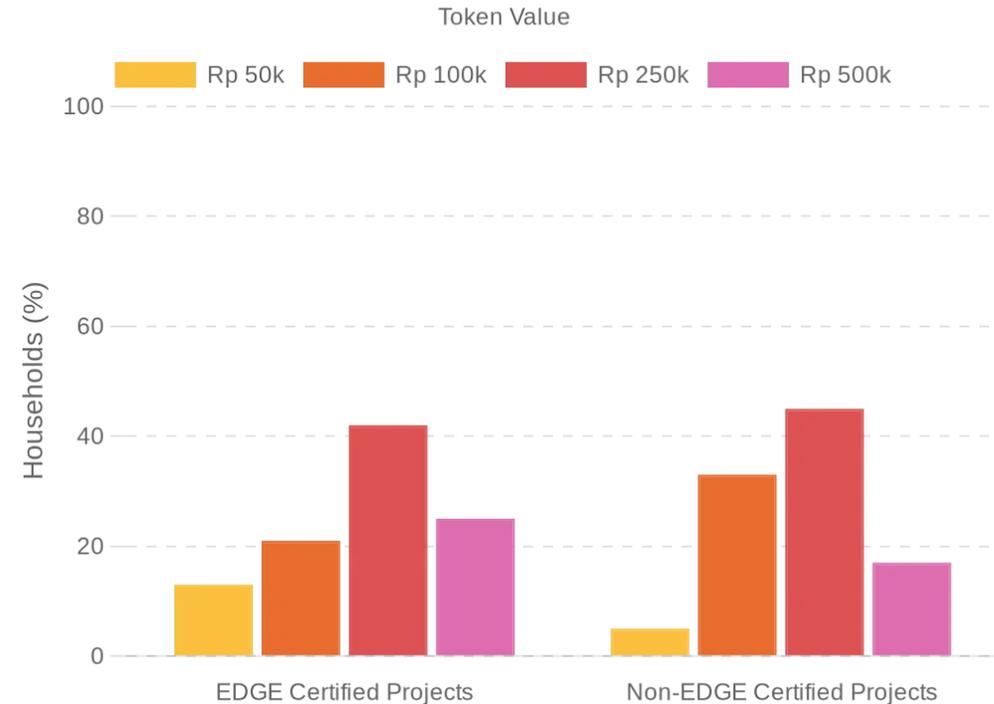
## Household and Demographic Data

Monthly Energy Consumption (House WITH AC) - Percentage



*As a tropical country with relatively constant temperature and humidity, cooling takes up the majority of energy load (40.2%). EDGE certified buildings are assumed to reduce energy consumption from cooling by optimizing design.*

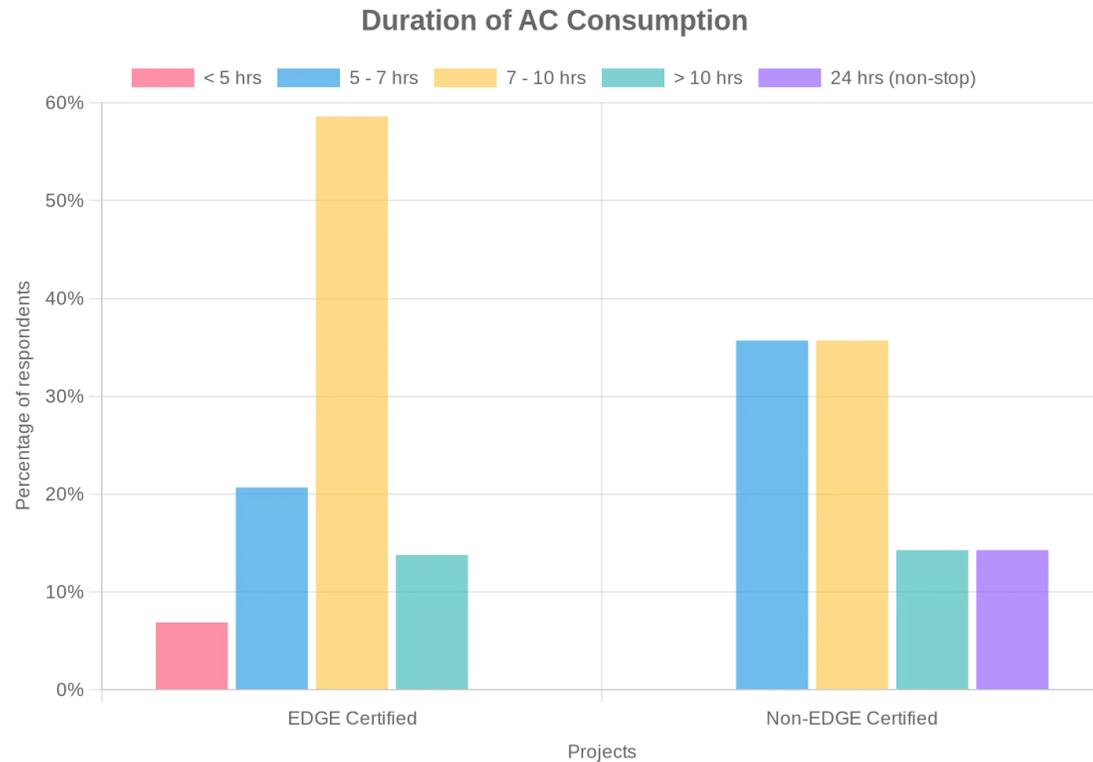
Monthly Electricity Token Purchase Distribution by Location



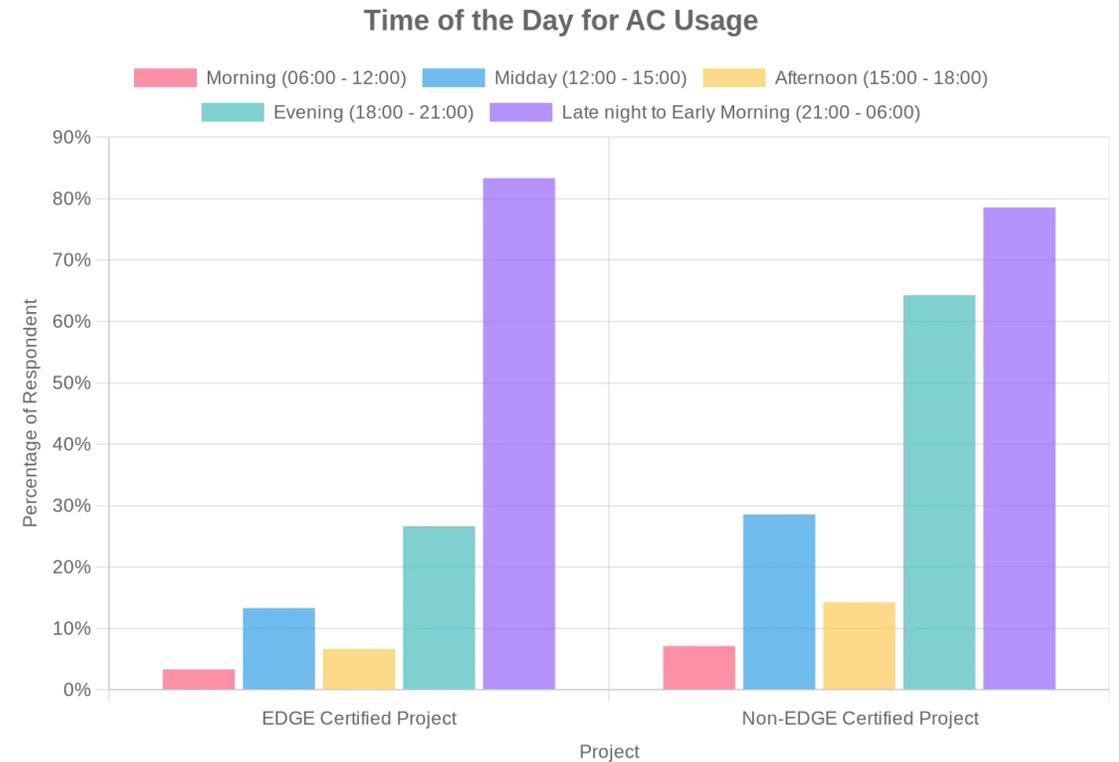
*Majority of the house top up the amount of 250 000 IDR (around 168 kWh credits). This number aligns with previous study in Indonesia.*

# Pilot Phase Findings

## Household and Demographic Data



*From the questionnaire results, most household turns on their AC for 7-10 hrs range. However, in non-EDGE Certified projects, some households turn on their AC for 24 hours.*



*Most household turns on their AC during late night to early morning, during sleeping/ resting time. However, in non-EDGE certified project, more households turn on their AC during evening and midday.*

# Pilot Phase Findings

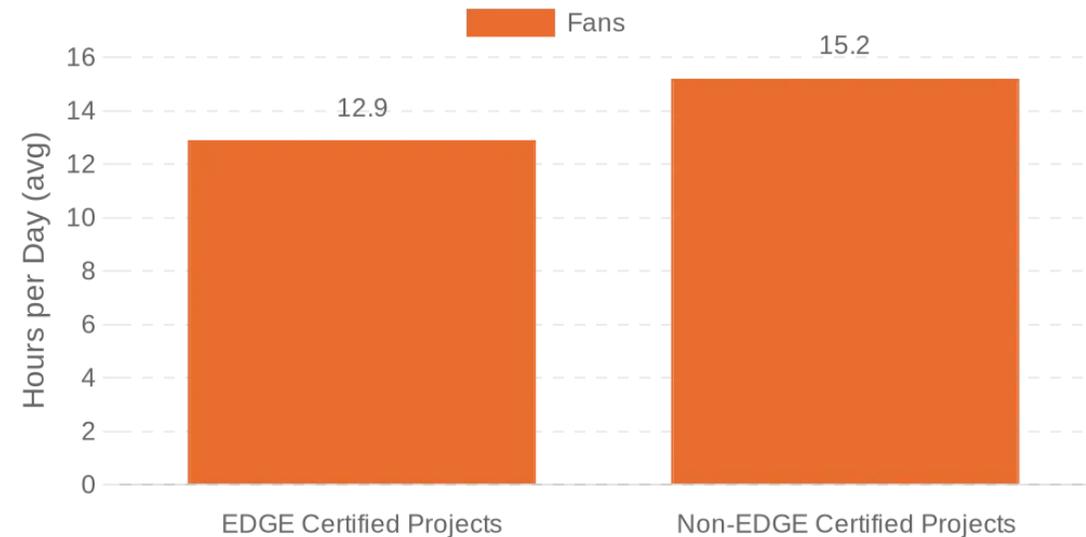
## Household and Demographic Data

Duration Category	Assumed Avg. Daily Hrs	Monthly kWh (if used at this rate)	EDGE certified project (% of Units)	non-EDGE certified project (% of Units)
< 5 hrs	3 hrs	45 kWh	6.9%	0%
5 - 7 hrs	6 hrs	90 kWh	20.7%	35.7%
7 - 10 hrs	8.5 hrs	127.5 kWh	58.6%	35.7%
> 10 hrs	12 hrs	180 kWh	13.8%	14.3%
24 hrs (non-stop)	24 hrs	360 kWh	0%	14.3%
<b>AVG Consumption</b>	-	-	<b>121.3 kWh</b>	<b>154.8 kWh</b>

By using assumed number of hours based on the ranges and proxy data about typical AC power input<sup>1</sup>, we estimate AC consumption by each project. By averaging hours of consumption by number of units, we discover that EDGE certified project consumes AC (cooling load) **21.64% lower** than its counterparts.

<sup>1</sup>CLASP, & Ipsos. (2020, June 8). Indonesia residential end-use survey: Final report. <https://www.clasp.ngo/wp-content/uploads/2021/01/Indonesia-Residential-End-Use-Survey.pdf>

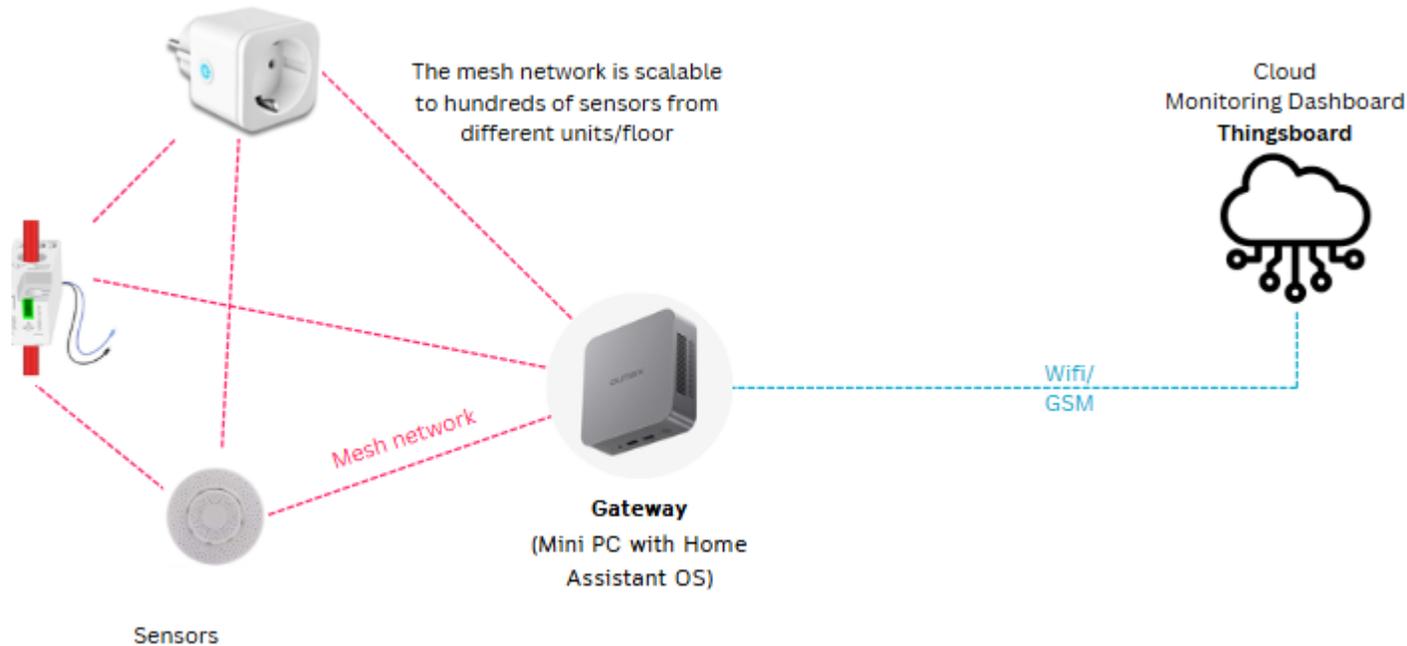
### Average Daily Usage Duration: AC vs Fans by Location



*We also discover that Non-EDGE Certified Projects use fans longer (2.3 hrs longer).*

# Pilot Phase

## Smart Monitoring Installations



*Ferbos Kreasi Digital provides a Zigbee-based system for environmental and energy monitoring. The system operates through a mesh network (bluetooth/ wifi).*

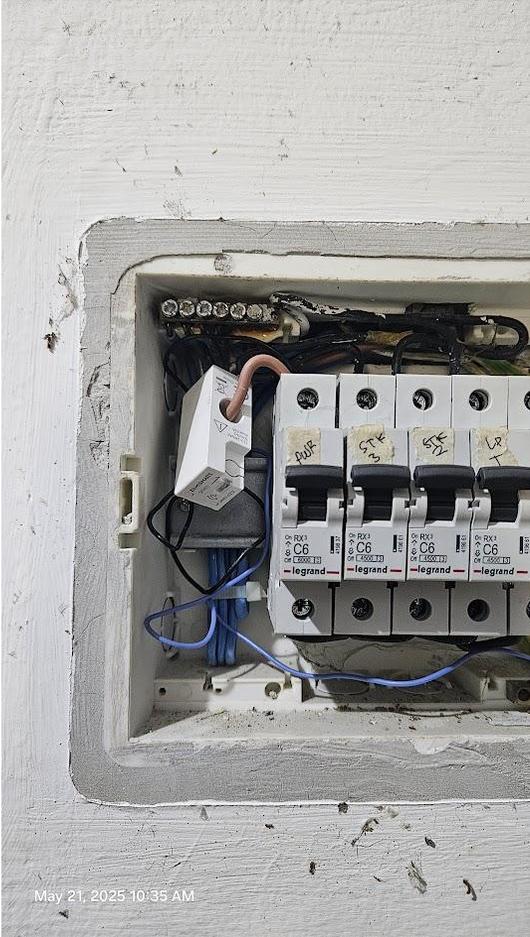
*Zigbee based:*

- *Cheap*
- *Scalable*
- *Ease of installation*

*Sensors installed in pilot phase:*

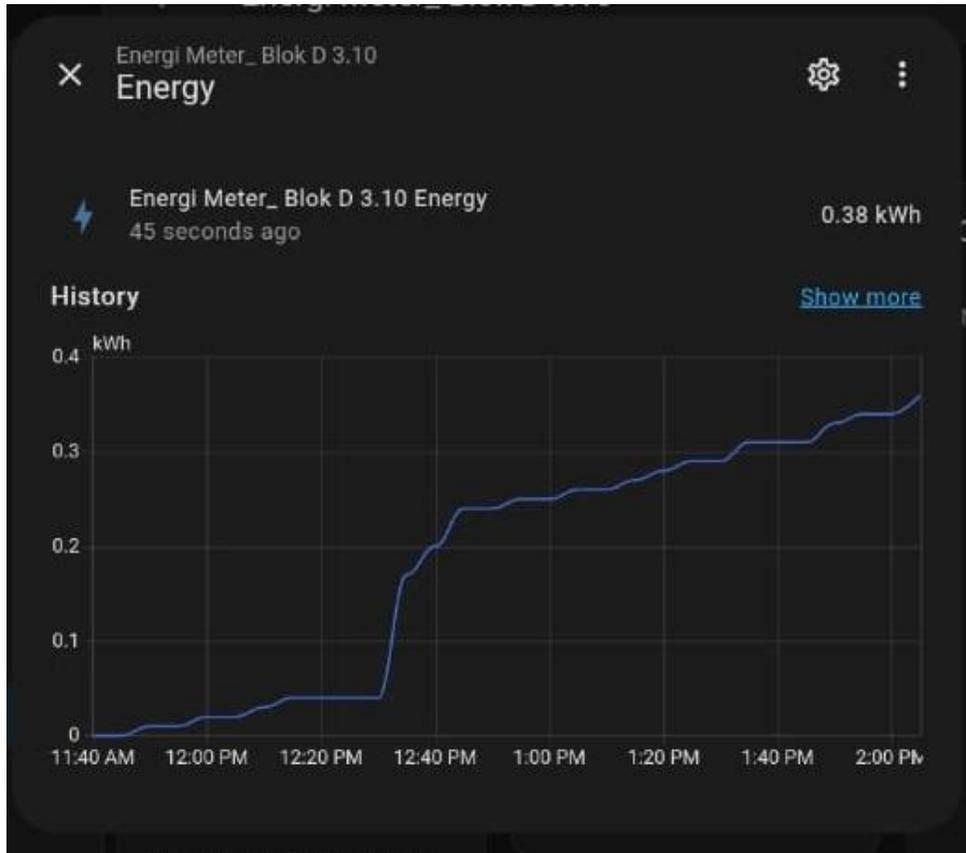
- *Energy meter*
- *Smart plug (for AC)*
- *IAQ Sensor*
- *PIR Sensor*

# Pilot Phase Smart Monitoring Installations



# Pilot Phase

## Smart Monitoring Installations



The screenshot shows a mobile app interface for an energy meter. At the top, it displays 'Energi Meter\_ Blok D 3.10'. Below this, there are several sections: 'Device info', 'Sensors', 'Automations', 'Scenes', and 'Scripts'. The 'Device info' section includes details about the smart energy monitor, its connection via Zigbee2MQTT Bridge, and hardware information. The 'Sensors' section lists various metrics: Current (0.6 A), Energy (0.39 kWh), Energy (0 kWh), Frequency (50 Hz), Power (139 W), and Voltage (232.2 V). There are also buttons for 'ADD TO DASHBOARD' and 'MQTT INFO'.

Sensor	Value
Current	0.6 A
Energy	0.39 kWh
Energy	0 kWh
Frequency	50 Hz
Power	139 W
Voltage	232.2 V

*Data can be exported to CSV.  
Data accuracy: 10W*

# Lesson Learnt

## For Main Phase

### Recruitment

- Door-to-door visits yield more trust.
- Brochure and online questionnaire still can be prepared to introduce before visits are made.
- Working with estate managers and community helped recruitment process.

### Engagement

- Providing the incentive right after completing the survey kept people involved.
- The incentive is sufficient to gain people's interest.
- Incentivizing estate managers and accompanying staff are also important.

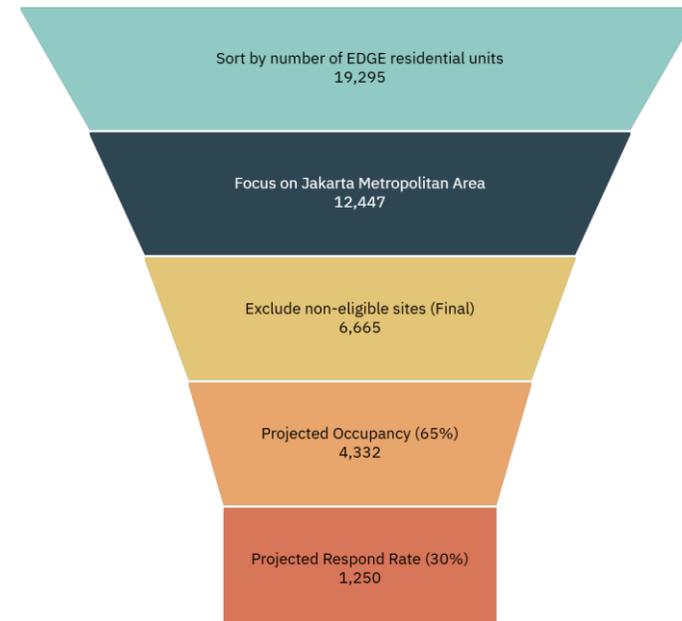
### Data Collection

- LLM works to reduce time required for manual readings.
- Developed standard field procedures are understood well.
- Face-to-face survey: 5-7 participants take 2 hours, with each survey takes 10 minutes. To reach our target (2500 units), more surveyors are required.

# Main Phase Targets

*Determining number of samples (EDGE)*

No.	Selection Process	Number of Units
1	Sort by number of EDGE residential units	19,295
2	Focus on Jakarta Metropolitan Area	12,447
3	Exclude non-eligible sites	6,665 → 3,894 (Preliminary) and 2,771 (Final)
4	Projected Occupancy (65%)	4332
5	Projected Respond Rate (30%)	1250



*Given above, our target:*

- **1,250 units (EDGE)**
- **1,250 units (non-EDGE counterfactual)**



**300 – 400 units** for smart monitoring equipment installation

**Thank you**



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# Study of Embodied Carbon in New Building Materials

**Arup**

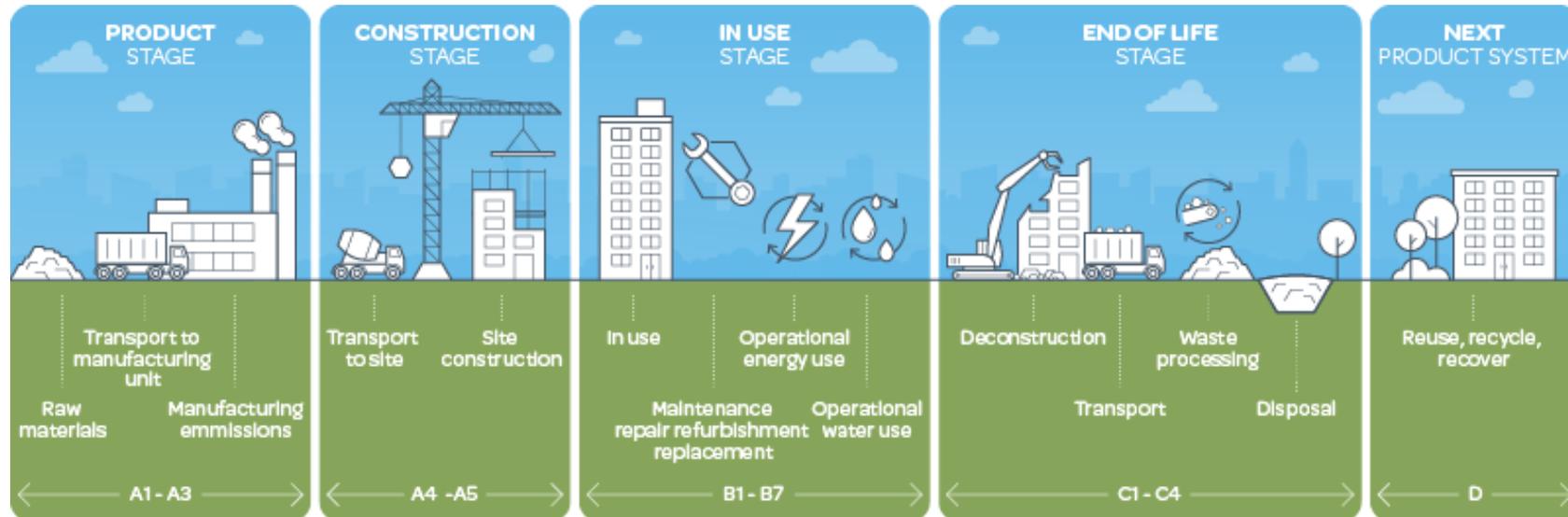
*EDGE is an innovation of IFC, a member of the World Bank Group.*

# Agenda

1. Technical background
2. Project drivers and key outputs
3. Building materials included in the study
4. Timelines and progress
5. The project delivery team

# What is whole life carbon assessment?

A whole life carbon assessment (WLCA) evaluates the carbon emissions associated with a building throughout its entire lifecycle. It considers both **‘embodied carbon’** and **‘operational carbon’**.



# What is embodied carbon?

- Carbon emissions associated with materials and construction processes, throughout the building's life cycle.
- This includes LCA modules A0–A5, B1–B5 and C1–C4.

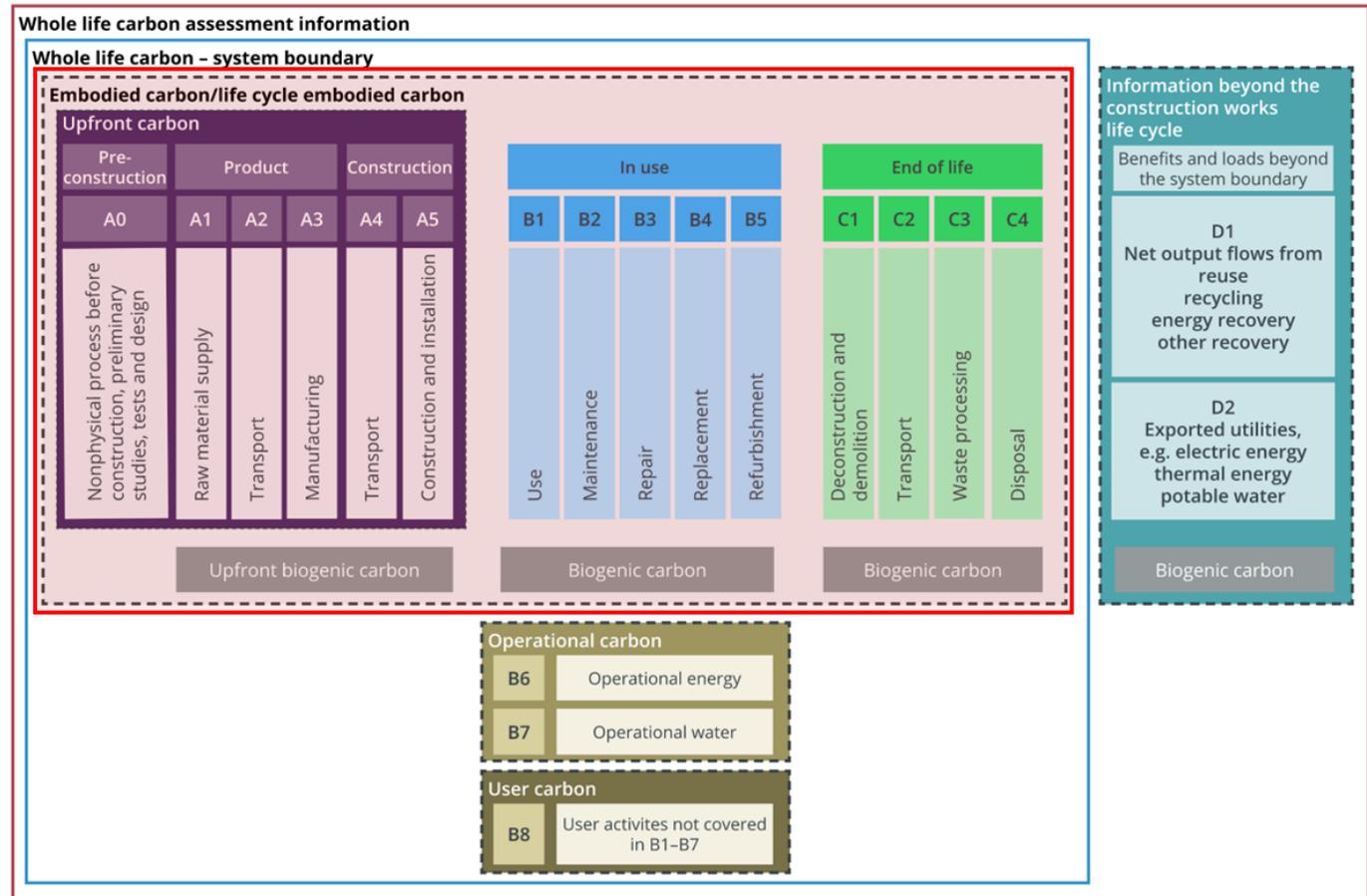
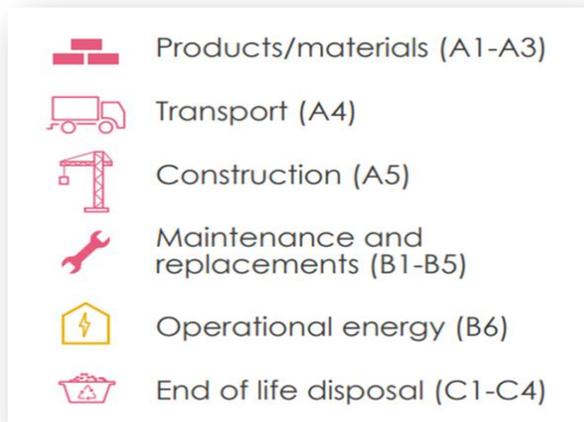
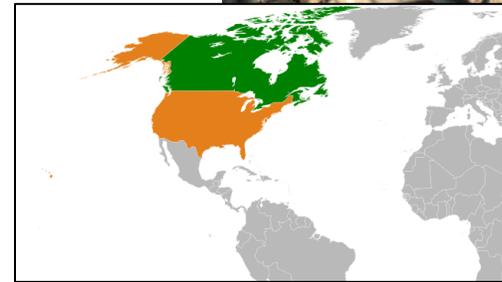


Figure source: RICS, 2024. Whole life carbon assessment for the built environment. Available from: [https://www.rics.org/content/dam/ricsglobal/documents/standards/Whole\\_life\\_carbon\\_assessment\\_PS\\_Sept23.pdf](https://www.rics.org/content/dam/ricsglobal/documents/standards/Whole_life_carbon_assessment_PS_Sept23.pdf)

# What are life cycle analysis (LCA) datasets?

Datasets quantifying the embodied carbon and energy for a given material, in a specific region, over its life cycle.

E.g., Rebar in the region of North America.



# Project drivers

## High quality data

Produce robust product-level LCA datasets for use in EDGE.

## Whole life cycle coverage

Expand from product-stage (A1-A3) to whole life cycle (A-C) datasets.

## More lower carbon materials

Focus on bio-based materials (timber, bamboo) and lower carbon steel and concrete.

## Geographic coverage

Produce datasets for all seven global regions (Africa, Asia, Central & South America, North America, Europe, Oceania, Middle East), while accounting for regional variation in material production and use.

# Key project outputs

1. **Embodied carbon and energy LCA ‘datasets’** covering LCA modules A-C, for concrete, steel, timber and bamboo, for all global regions.
2. **Methodology and Findings Report** outlining how material-region combinations were selected, how the product-level LCAs were undertaken, and how some embodied carbon emissions should be calculated in EDGE at the building-level.
3. **Training materials** for EDGE users on including less carbon intensive structural materials on projects.
4. **New structural assemblies** to be available in EDGE, covering the new materials researched, plus substructure assemblies.

# Which materials are included?

Concrete



Steel



Timber



Bamboo



Group	Material description	Regions
Concrete	<ul style="list-style-type: none"> <li>• Ready-mix concrete, OPC (ordinary Portland cement), C30 &amp; C40</li> <li>• Ready-mix concrete, OPC + limestone, C30</li> <li>• Ready-mix concrete, OPC + fly ash (30%), C30</li> <li>• Ready-mix concrete, OPC + GGBS (25%), C30</li> <li>• Ready-mix concrete, OPC + GGBS (50%), C30</li> <li>• Ready-mix concrete, OPC + calcined clay + limestone, C30</li> </ul>	<p>All global regions where applicable (i.e., where the SCM is generally available and used).</p> <p>Calcined clay mixes: countries where production exists (Brazil, Colombia, Ghana, Cote d'Ivoire, Angola, Cameroon, France, USA).</p>
Steel	<ul style="list-style-type: none"> <li>• Steel reinforcement (rebar)</li> <li>• Steel section (open)</li> <li>• Steel section (closed)</li> <li>• Steel plate</li> <li>• Galvanised steel frame (light gauge)</li> <li>• Galvanised steel sheet</li> </ul>	<p>All 7 global regions (Africa, Asia, Middle East, Europe, Central and South America, North America, Oceania).</p>
Timber	<ul style="list-style-type: none"> <li>• Plywood</li> <li>• Glue-laminated untreated softwood timber (glulam)</li> <li>• Medium density fibreboard (MDF)</li> <li>• Particleboard</li> <li>• Sawn timber (air dried/green)</li> <li>• Sawn timber (kiln dried)</li> </ul>	<p>All 7 global regions.</p>
Bamboo	<ul style="list-style-type: none"> <li>• Bamboo pole (boron treated and kiln dried)</li> <li>• Bamboo pole (boron treated and air dried)</li> </ul>	<p>Where bamboo use is prevalent and data is shared with us: Ecuador, Costa Rica, Mexico, Indonesia, Nepal, Philippines (plus regions of Asia, Central &amp; South America, global).</p>

# Key considerations in selection of materials

1. Aimed for wide geographic coverage of most-used structural materials.
2. Supersede existing EDGE datasets because of the change in LCA scope (previously A1-A3, now A-C), providing methodological consistency.
3. Aim to prevent higher-than-regional-average use of resource-constrained materials (e.g., GGBS, steel scrap) and instead encourage greater use of lower carbon materials that are abundant and/or bio-based.

## Timelines

Duration: Two years

Project start: April 2024

Project completion: 31 March 2026

**Currently about half-way through the project programme.**

# Project delivery team on the call



Sean Lockie  
Project Director  
Arup



Matthew Munro  
Project Coordinator  
Arup



Sara Dethier  
Project Manager  
Arup

# Wider delivery team



ConstructionLCA

Thank you!