DISTRIBUTION NETWORK PLANNING FOR ISOLATED MINI-GRIDS: A NOVEL APPROACH

Lina Silva Rodriguez. Utrecht University, VITO, and Energyville
Stefano Mandelli, CESI S.p.A
Fabio Riva, CESI S.p.A
Elena M. Fumagalli, Utrecht University

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Utrecht University

AGENDA

1. INTRODUCTION
Motivation

2. MATERIAL AND METHODS: RETEP NETWORK
Modelling methodology and implementation

3. APPLICATION TO TEST CASE
Village in Ethiopia

4. RESULTS AND DISCUSSION
Comparative Analysis

5. CONCLUSIONS
Final remarks

1. INTRODUCTION

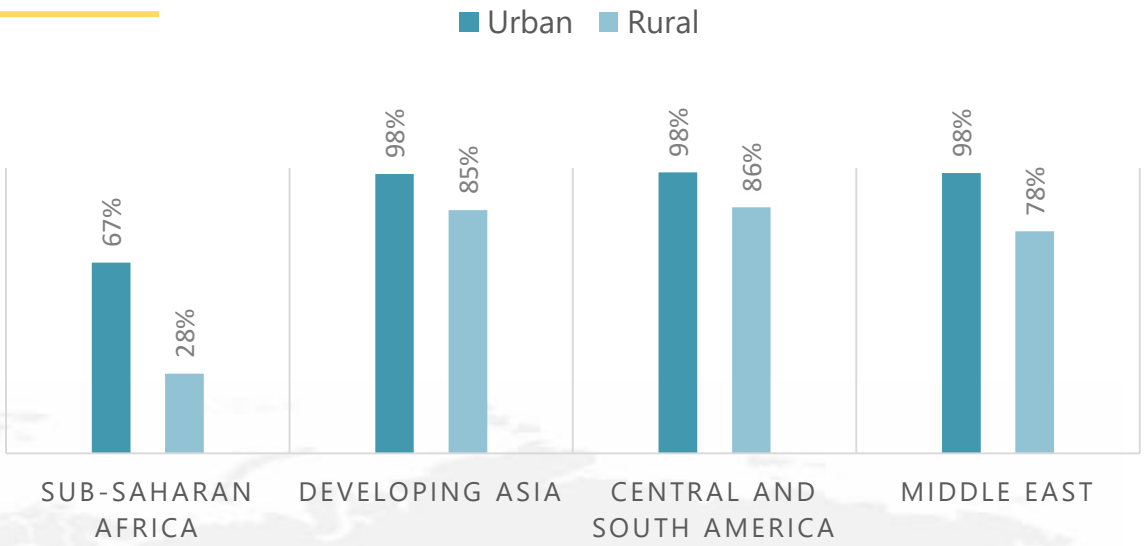
SDG 7. Affordable and clean energy: universal energy access, energy efficiency and renewable sources by 2030.

Source: United Nations

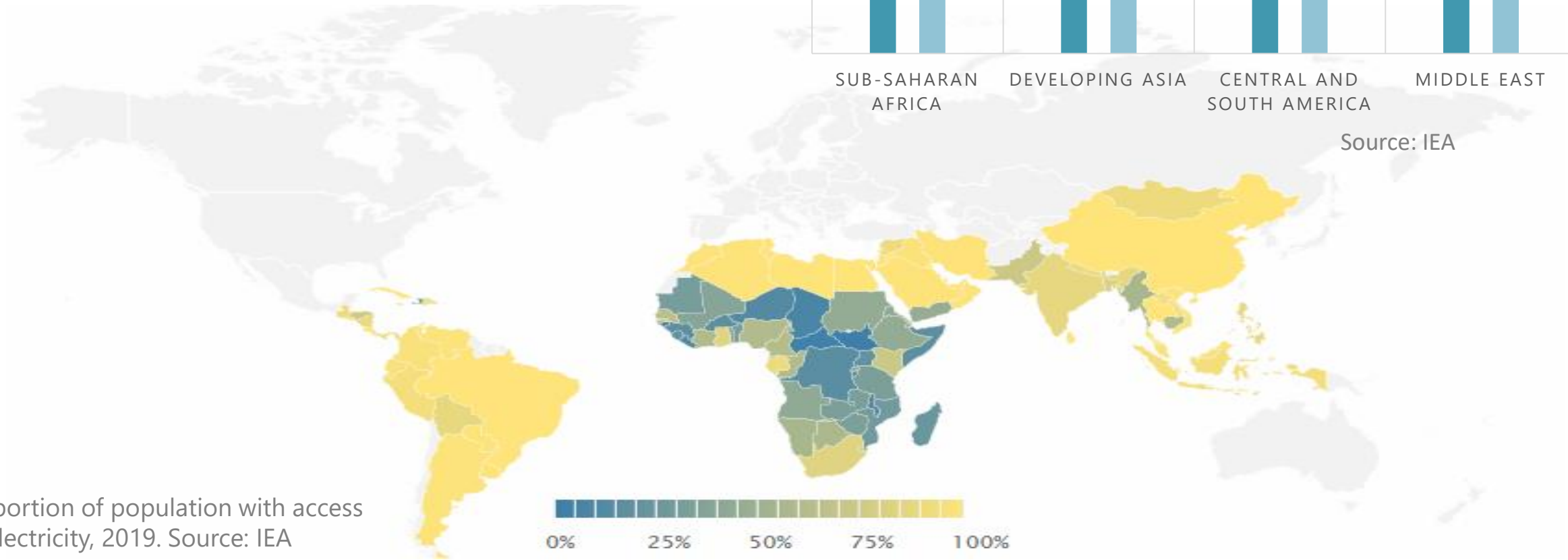
ENERGY ACCESS

770 million people lack electricity access (IEA,2019)

8.7 out of 10 people without electricity service are located in rural areas. (United Nations, 2018)



Source: IEA



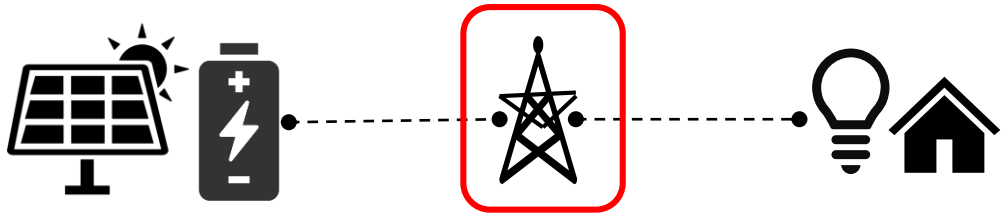
Proportion of population with access to electricity, 2019. Source: IEA

1. INTRODUCTION

PROBLEM AND OBJECTIVE

- On-grid
- **Off-grid**

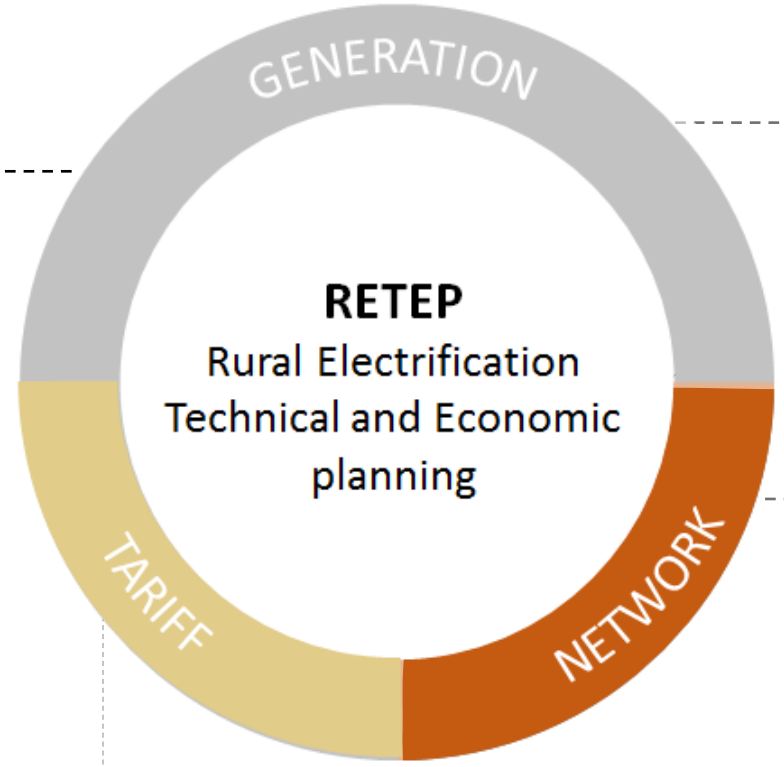
Decentralized solutions are often the cheapest way to electrification remote in rural areas.



The main goal is to develop a tool based on geospatial information, which is able to provide the user with **a preliminary optimized topology** of the distribution network for the feasibility analysis of isolated mini-grids

2. MATERIAL AND METHODS: RETEP NETWORK

Simplified method



- **Generation capacity planning** for electrification of isolated areas
- Multiple configurations (e.g., Stand-alone, PV+wind microgrid)

- **Distribution network planning** for isolated microgrids
- Minimize the total length of the network

- **Assessment of the financial viability**
- Comparison of different tariff models

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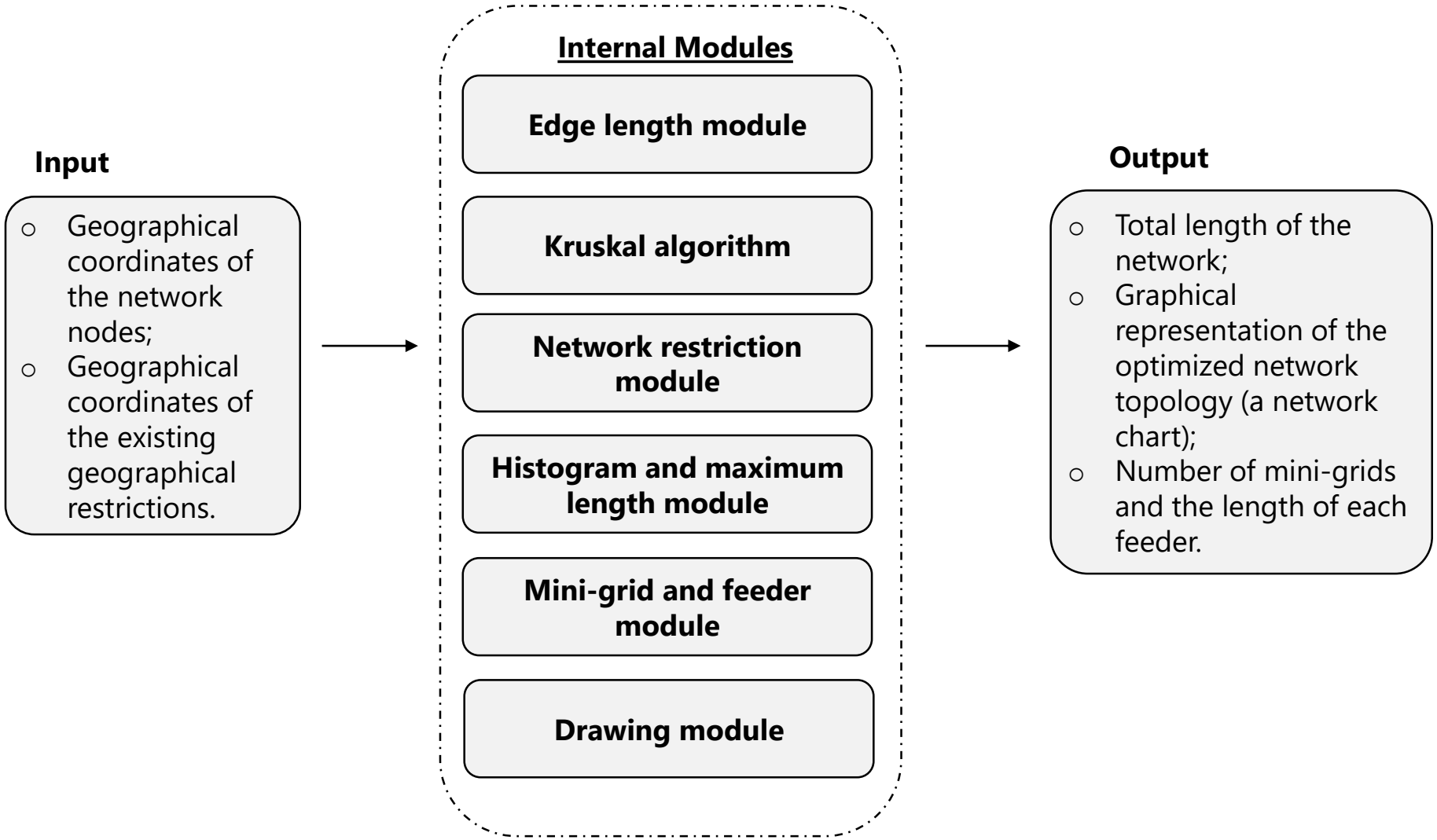
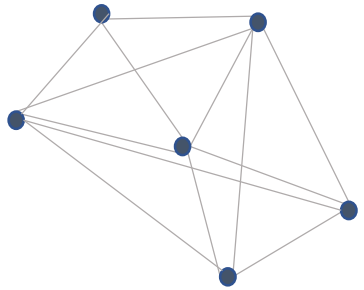
2. MATERIAL AND METHODS: RETEP NETWORK



2. MATERIAL AND METHODS: RETEP NETWORK

Internal Modules

- **Edge length module**
- **Kruskal algorithm**
- **Network restriction module**
- **Histogram and maximum length module**
- **Mini-grid and feeder module**
- **Drawing module**



Haversine formula:

$$d = 2r\sin^{-1}\left(\sqrt{\sin\left(\frac{\varphi_2-\varphi_1}{2}\right)^2 + \cos(\varphi_1)\cos(\varphi_2)\sin\left(\frac{\omega_2-\omega_1}{2}\right)^2}\right)$$

Output:

- Graph with nodes and edges
- Edges' length

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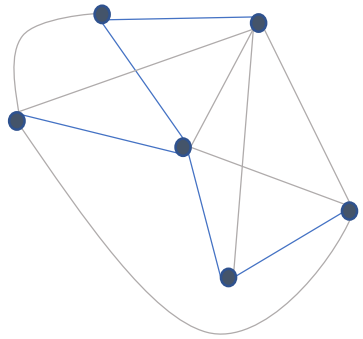

The distribution network problem is addressed as a **minimum spanning tree:**

Prim Algorithm
Kruskal Algorithm
Dijkstra Algorithm

Problem: Given a simple graph G (V, E) find the minimum spanning tree.

- **Sort all the edges** in non-decreasing order of their weight (length).
- Select the edge with the **least length**. Check if by including this edge there are formation of cycles in the formed spanning tree.
- Repeat the process until all the nodes are connected.

Output:

- List of selected edges
- Total length of the tree

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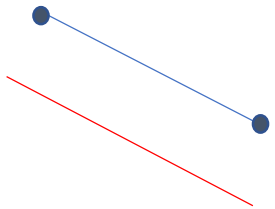
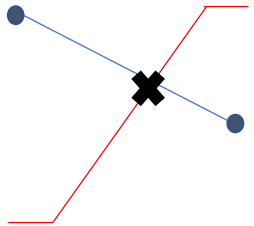
Retep Network is able to **force or avoid** certainly paths according to user's preferences or topography restrictions.

Type I		Restrictions that must be avoided
Type II		Restrictions that might be crossed if necessary (penalty)
Type III		Activated/deactivated by the planner





Output:

- List of restricted edges

2. MATERIAL AND METHODS: RETEP NETWORK

Internal Modules

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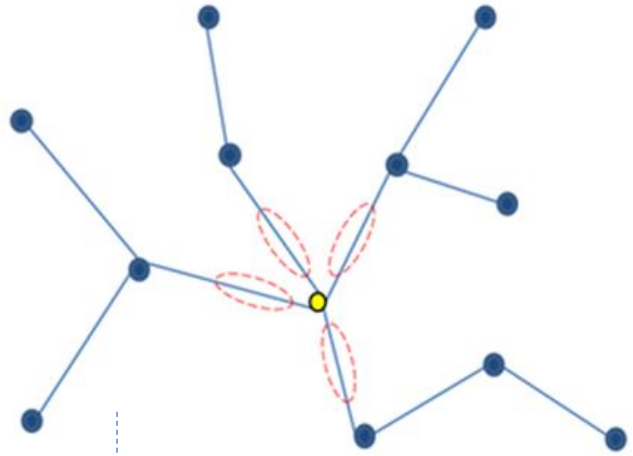
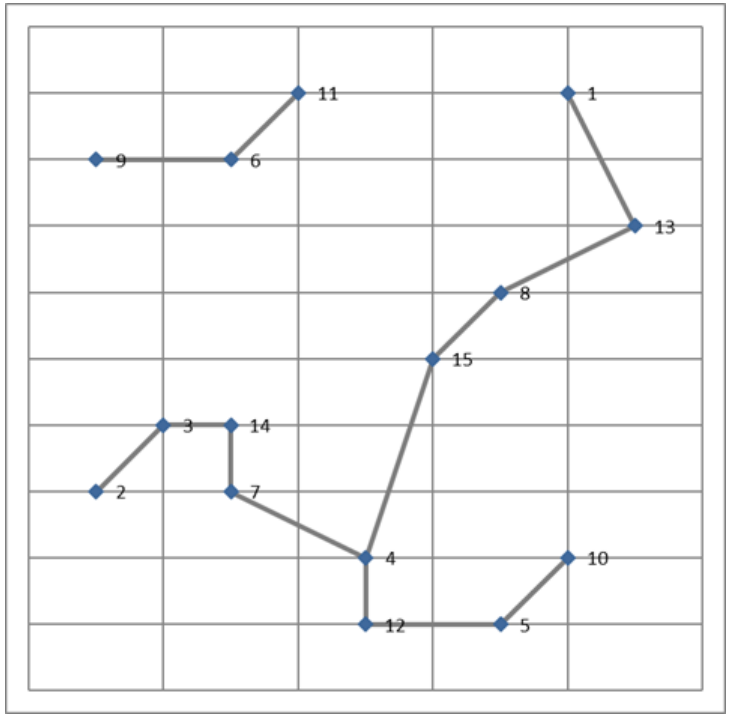
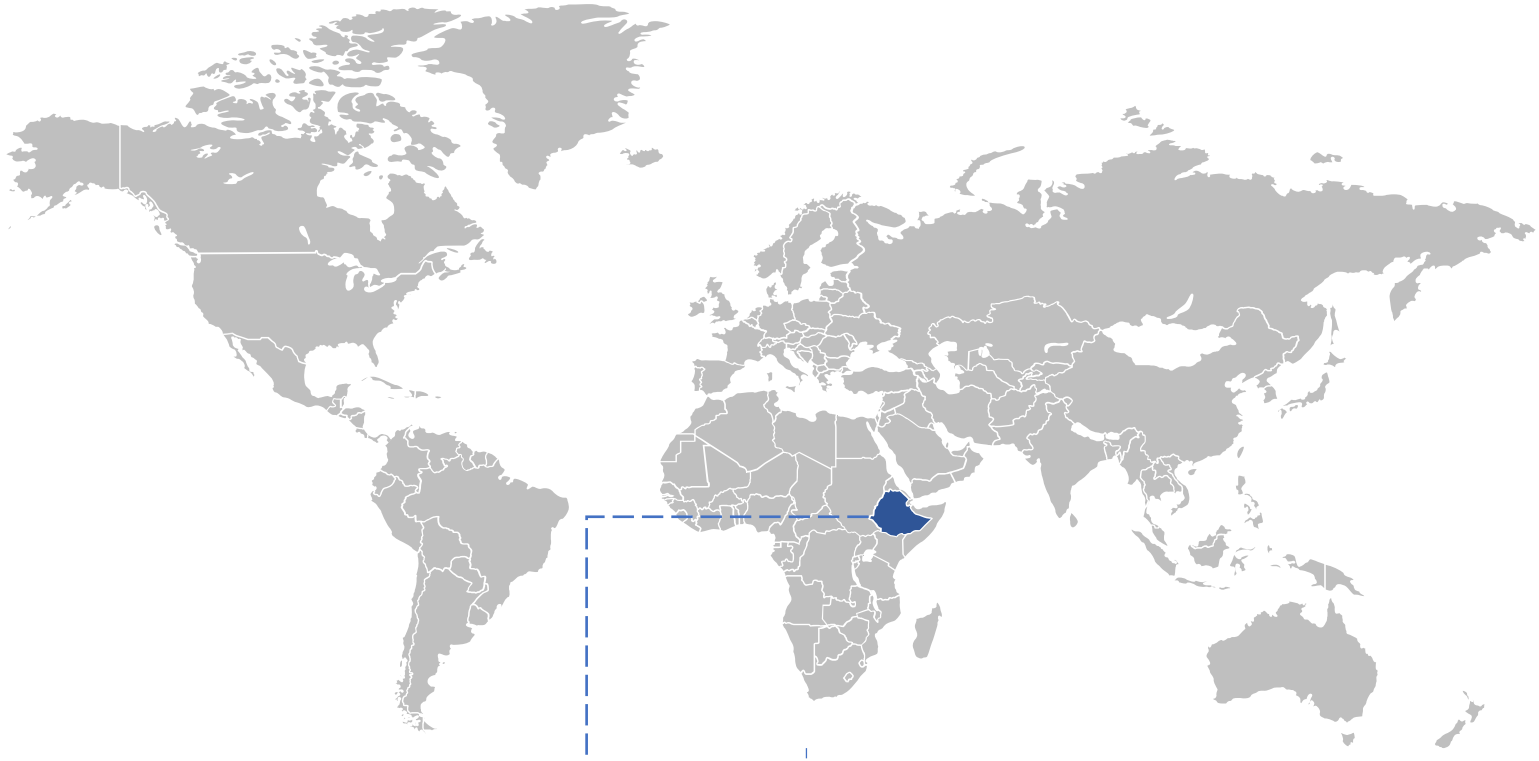


- Total Length
- N° Microgrid
- N° Users
- N° Gen.
- N° Feeders
- N° user by categories
- Max Demand
- Min Demand

Additional input from RETEP-G



3. APPLICATION TO REAL CASE STUDIES



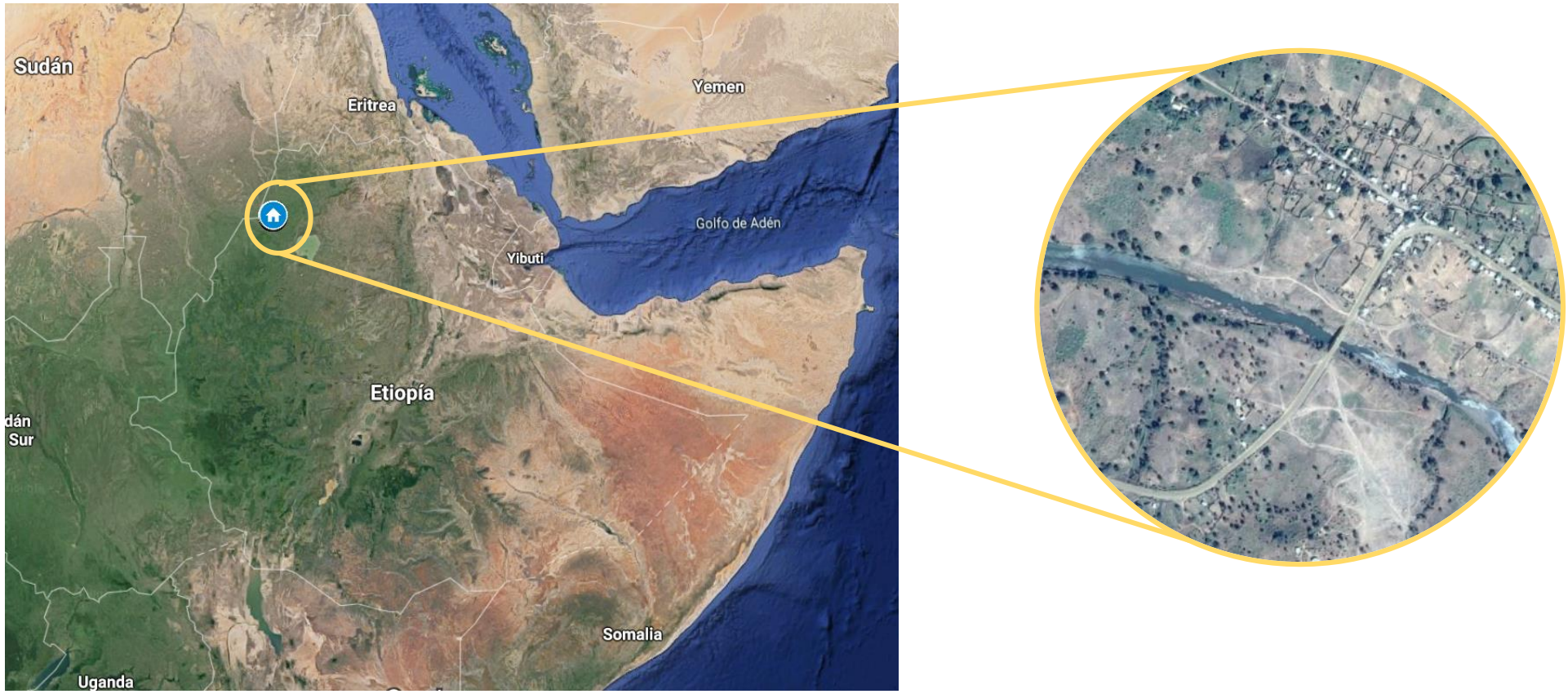
Village located in Ethiopia.

141 users / nodes.
6 scenarios

Two main restrictions**: a river and a main road.**

3. APPLICATION TO REAL CASE STUDIES

ETHIOPIA CASE STUDY



3. APPLICATION TO REAL CASE STUDIES

ETHIOPIA CASE STUDY

Source: Google Maps

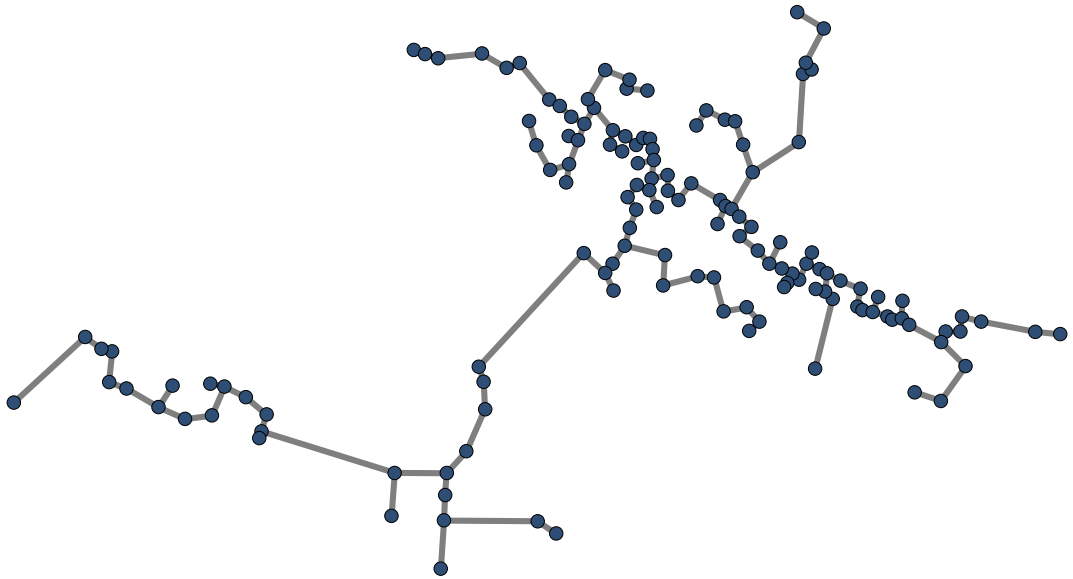
USER	QUANTITY
School	2
Pharmacy	2
Carpenter	3
Market	4
Small Enterprise	1
Barber	1
Household C1	29
Household C2	29
Household C3	14
Household C4	15
Household C5	40

3. APPLICATION TO REAL CASE STUDIES

ETHIOPIA CASE STUDY

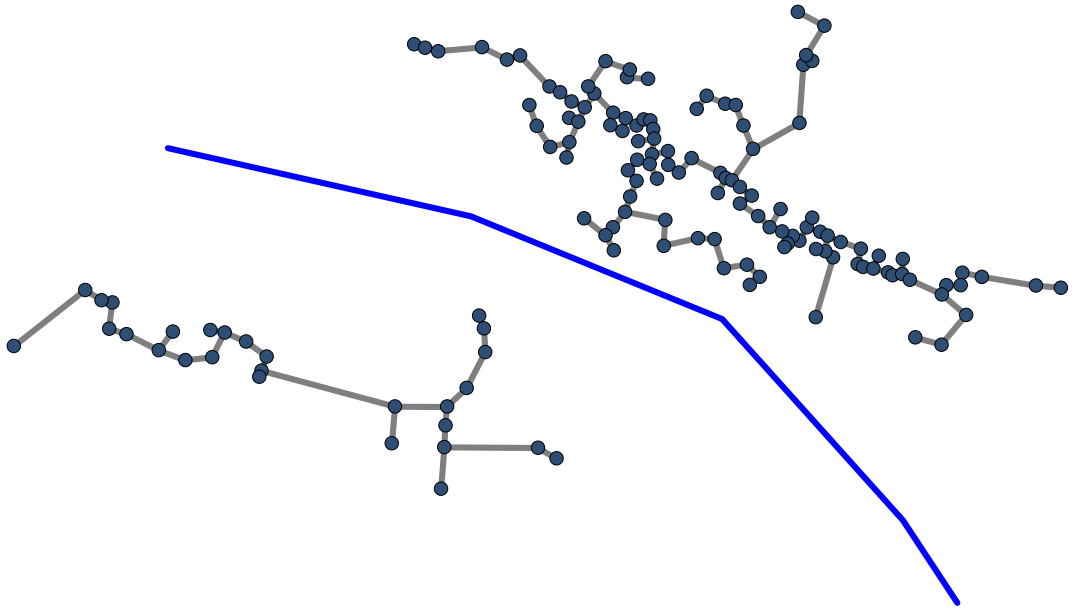
Micro grids	1
Total Length [m]	6898.56
Users	141
Add. Poles	0
Generators	0

Scenario 1: Ideal case



Micro grids	2
Total Length [m]	6586.65
Users	141
Add. Poles	0
Generators	0

Scenario 2: Restriction type I- River. The river cannot be crossed

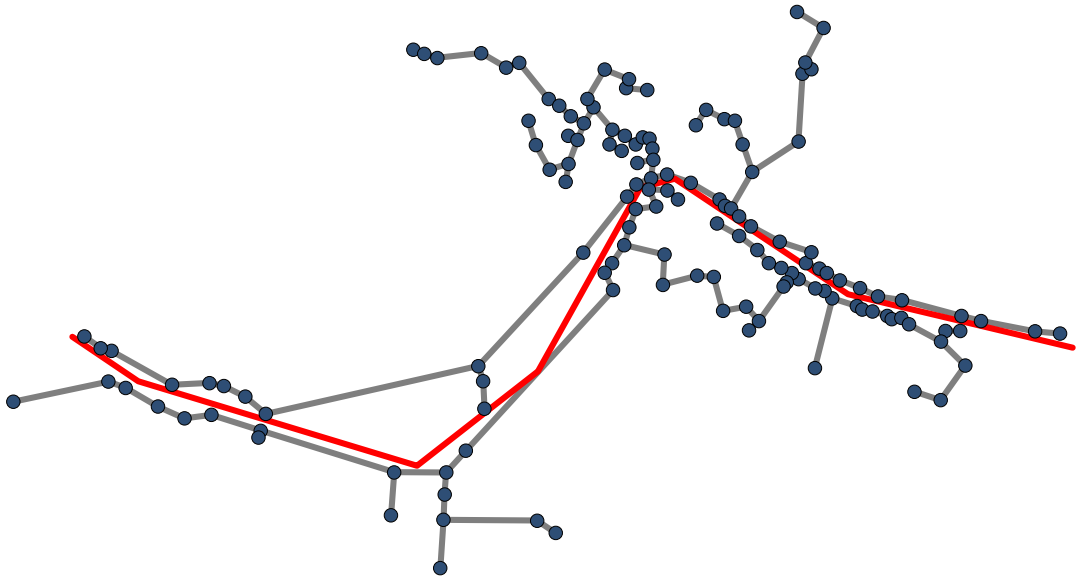


3. APPLICATION TO REAL CASE STUDIES

ETHIOPIA CASE STUDY

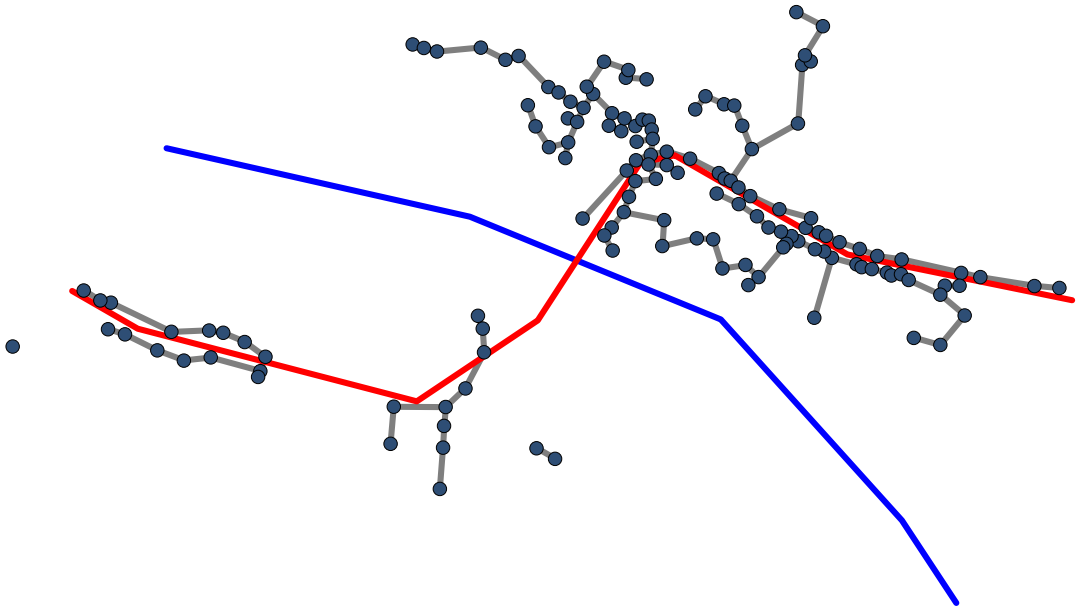
Micro grids	1
Total Length [m]	8188.80
Users	141
Add. Poles	0
Generators	0

Scenario 3a: Restriction type II- Road. The tool decides where to cross the road



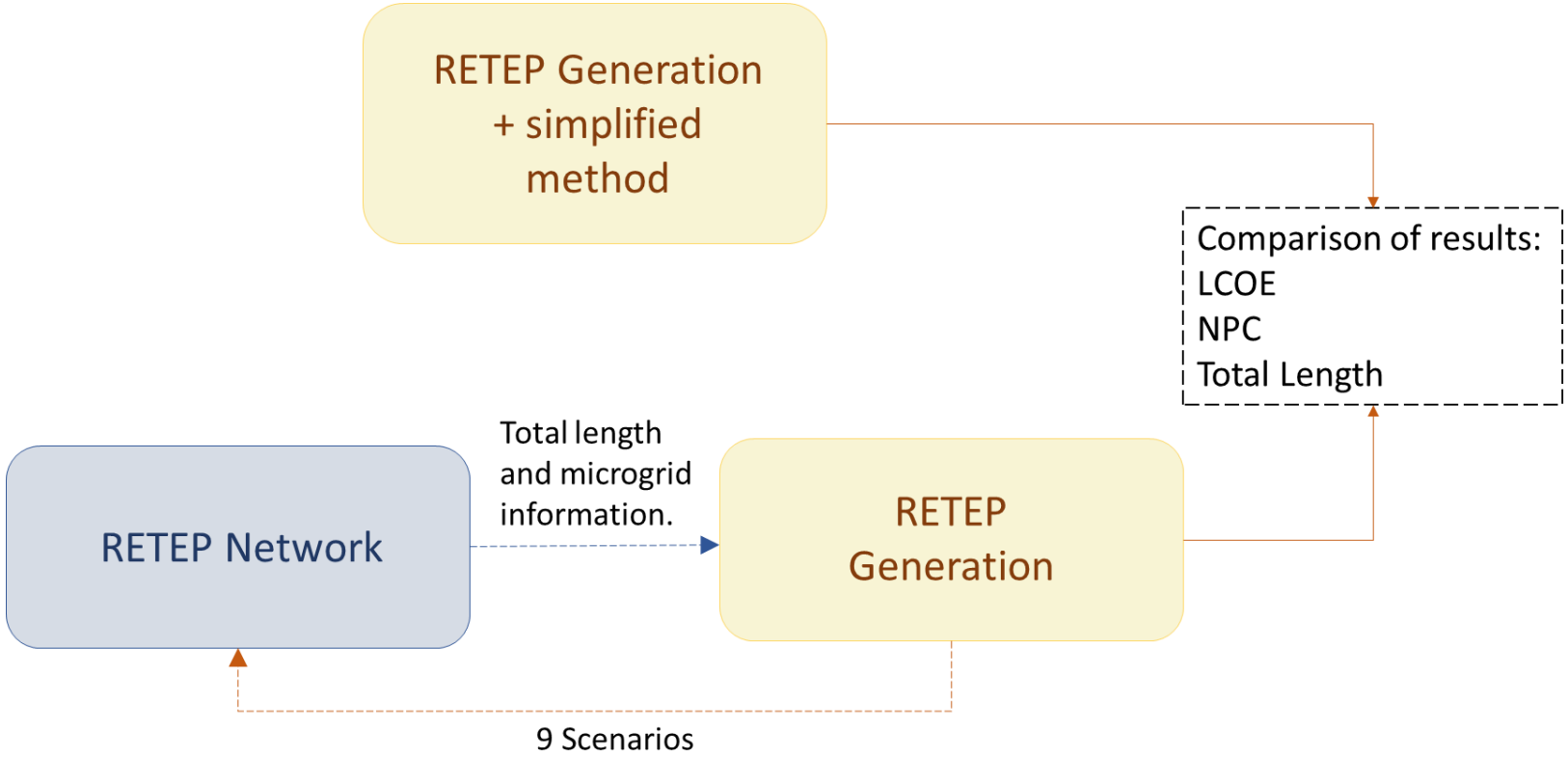
Micro grids	5
Total Length [m]	6437.80
Users	141
Add. Poles	0
Generators	0

Scenario 5: Histogram- Maximum length limit 170 m



3. APPLICATION TO REAL CASE STUDIES

COMPARATIVE ANALYSIS



The simplified method is based on **Nearest Neighbour Analysis:**

- Allows to calculate the average distance between points randomly distributed in the space.
- This distance has to be multiplied by the number of buildings to get the length of the micro-grid.

Limitations:
-Cannot be used in irregular areas
-Assumes that all the points are randomly distributed

$$E(d_i) = 0.5\sqrt{\frac{A}{N}} + \left(0.0514 + \frac{0.041}{\sqrt{N}}\right)\frac{B}{N}$$

Input:
-Area
-Perimeter
-Nodes

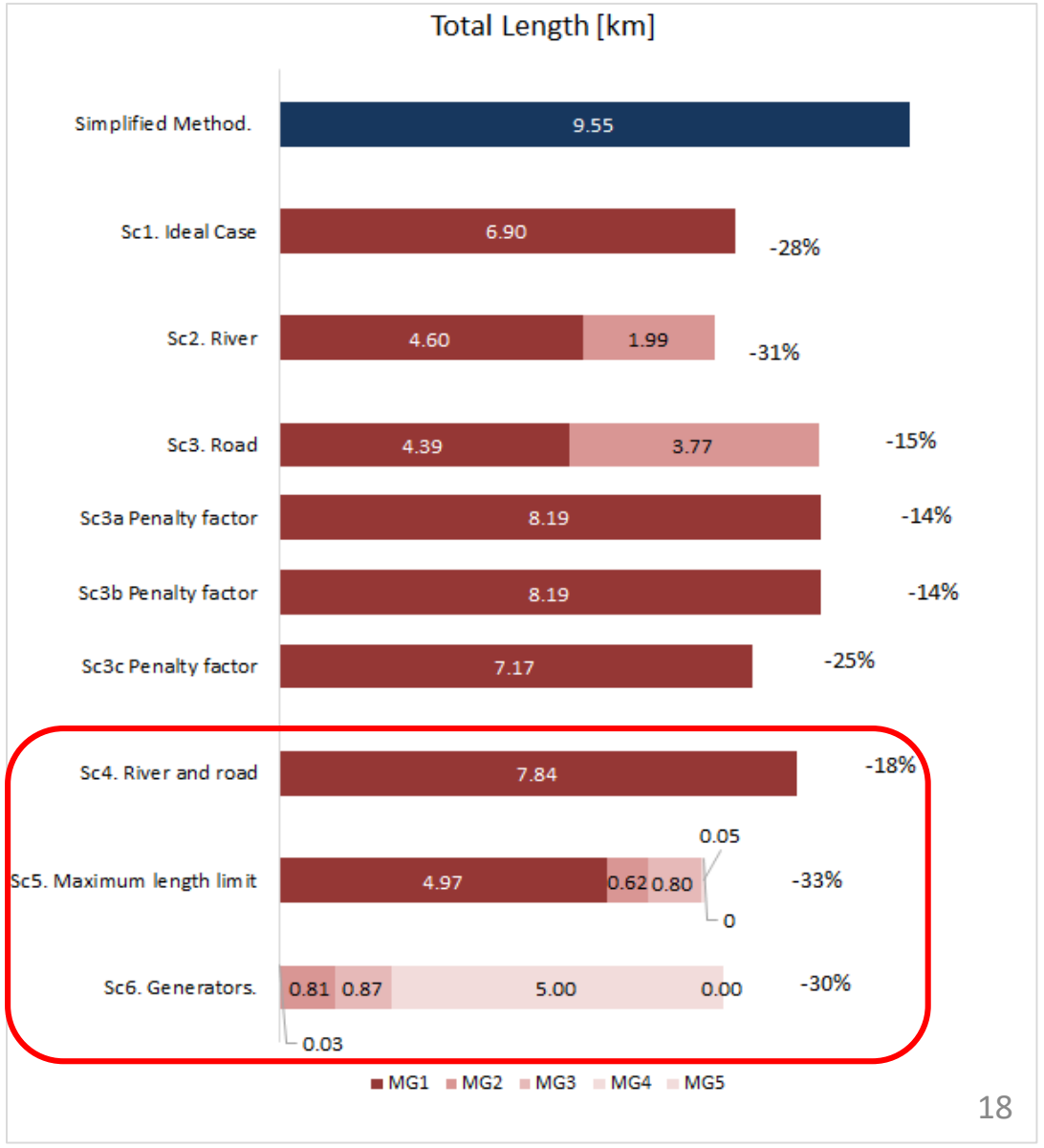
Output:
-Total length

4. RESULTS AND DISCUSSION

COMPARATIVE ANALYSIS
TOTAL LENGTH

The network length calculated by the simplified method (9.55km) is greater than the aggregated length of the corresponding microgrids defined **by RETEP Network**.

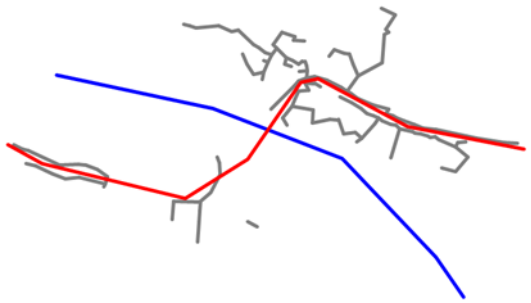
In the more realistic scenarios, the defined network length was in **all cases shorter** than the one calculated by the simplified method. (18%- 33%)

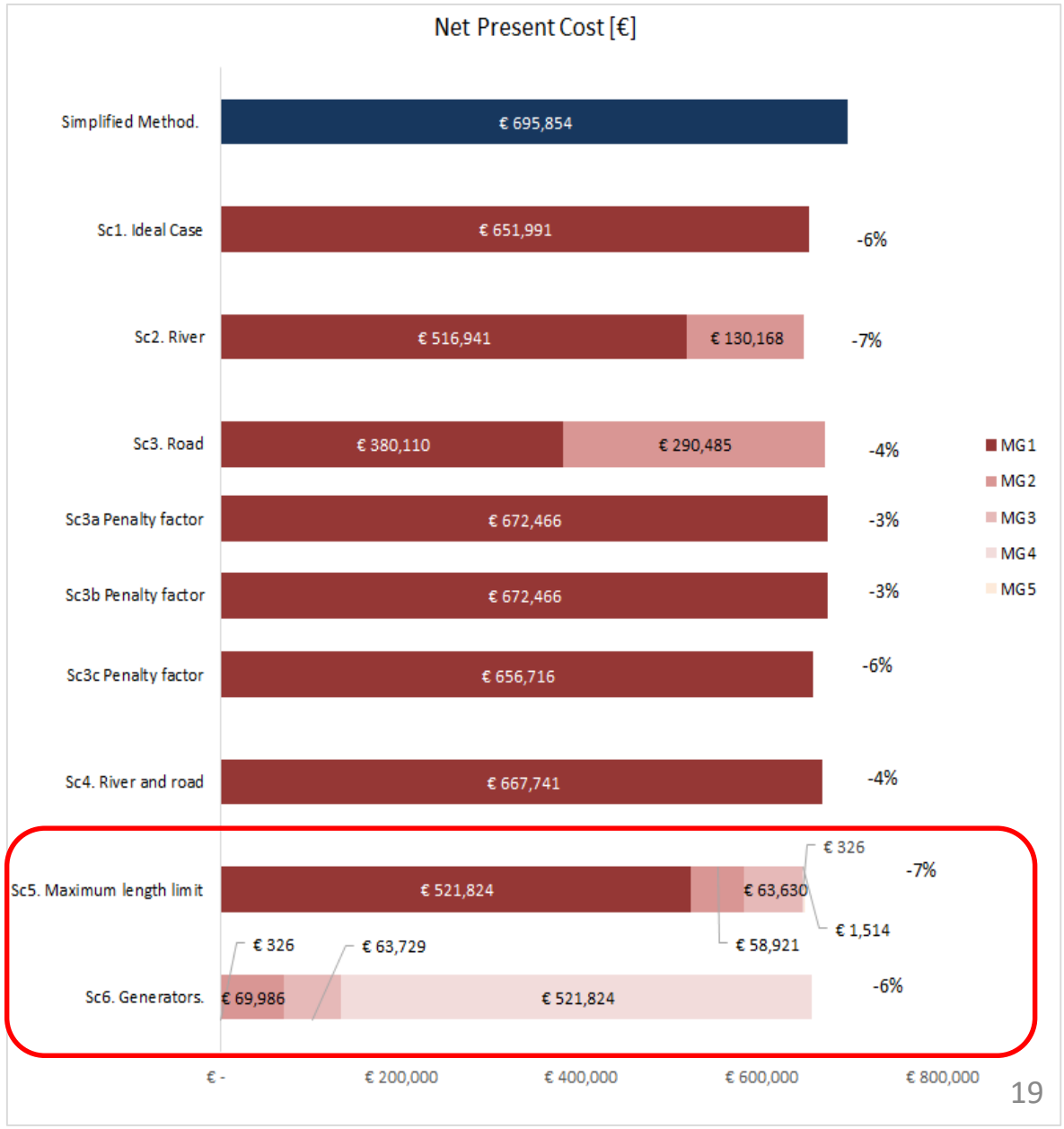


4. RESULTS AND DISCUSSION

COMPARATIVE ANALYSIS
NET PRESENT COST

RETEP Network not only optimises the total length but allows the user **to find more economical solutions** when considering multiple configurations and the separation of microgrids.

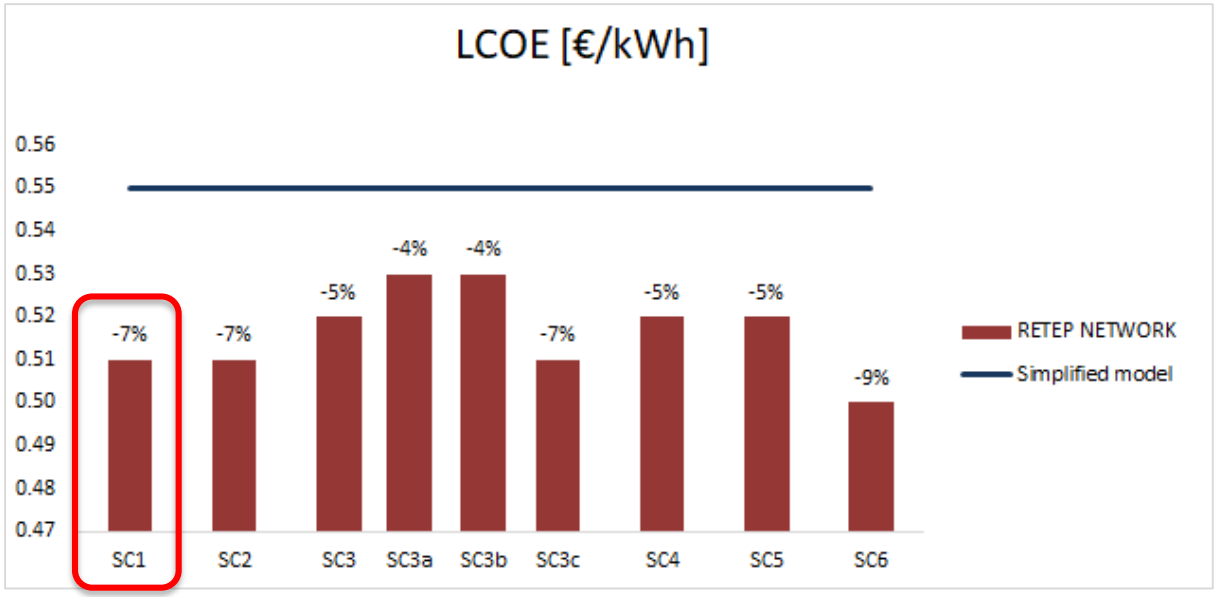


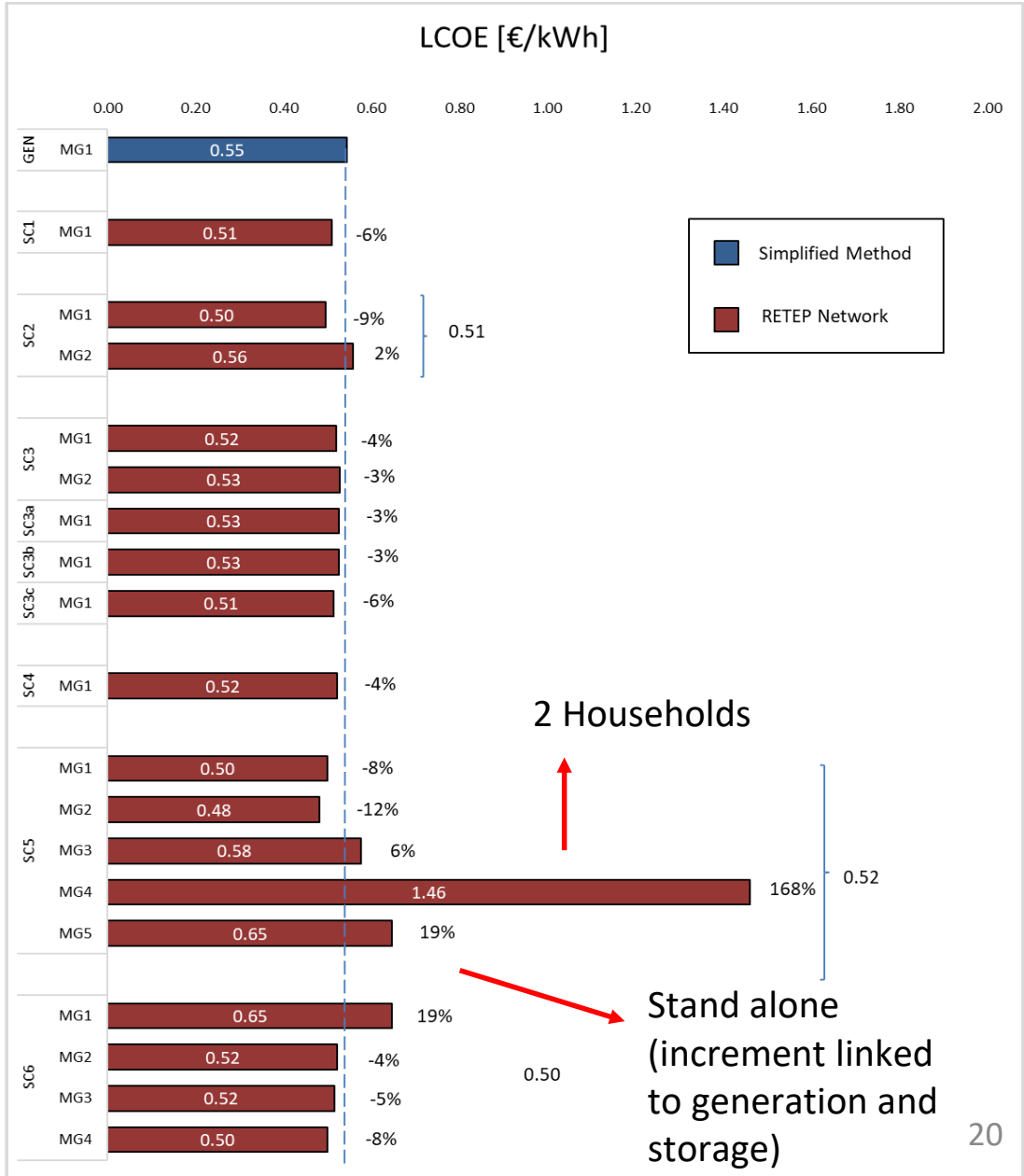


4. RESULTS AND DISCUSSION

COMPARATIVE ANALYSIS
LEVELIZED COST OF ELECTRICITY

The results here are consistent with those observed before; the LCOE is lower in all the cases as total length and NPC are lessened using RETEP Network.





4. FINAL REMARKS ON THE CASE STUDY

- RETEP-N is a intuitive, easy-to-use software tool, with low machine specs requirements.
- The optimization of the network topology is an important element in the minimisation of the project cost.
    - Multiple mini-grids can result in considerable savings.
- Much higher cost per mini-grid when the number of end-users connected is small.
    - Stand alone is a feasible option.

THANK YOU!