# Last Mile Connectivity Solution: Toolkit

Online
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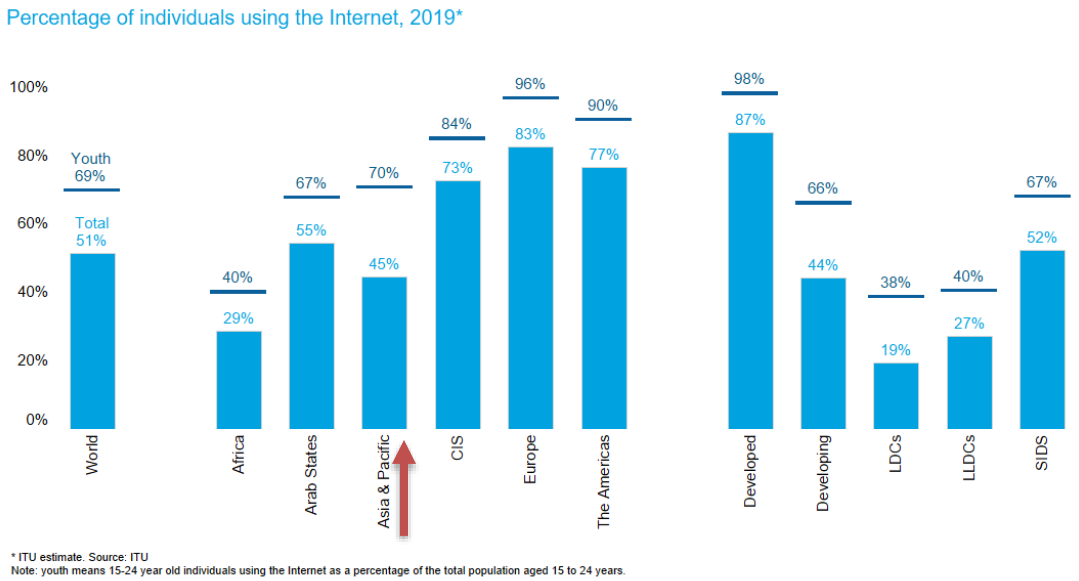
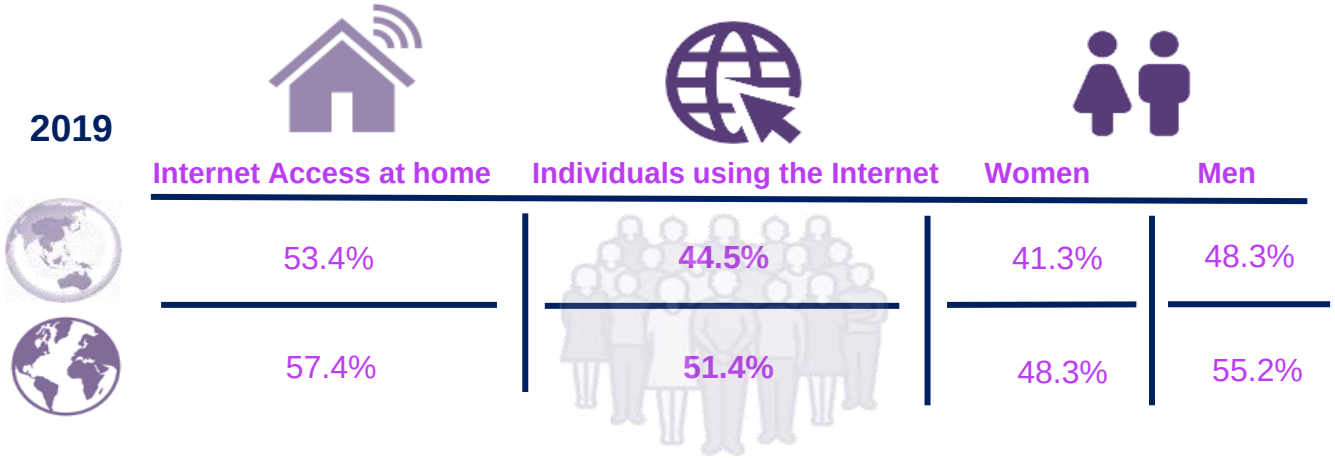
# Scope

- Why the requirement?
- Toolkit
- Going Ahead

# Regional Background

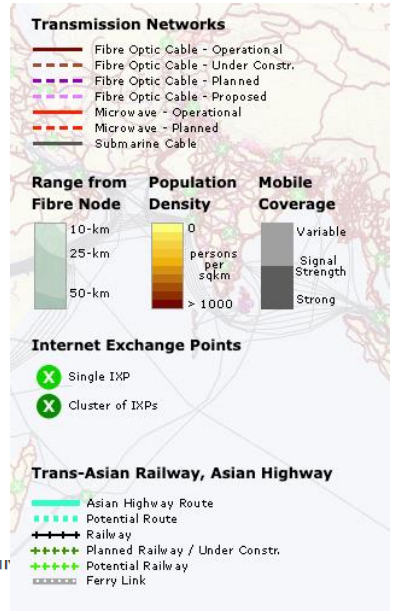


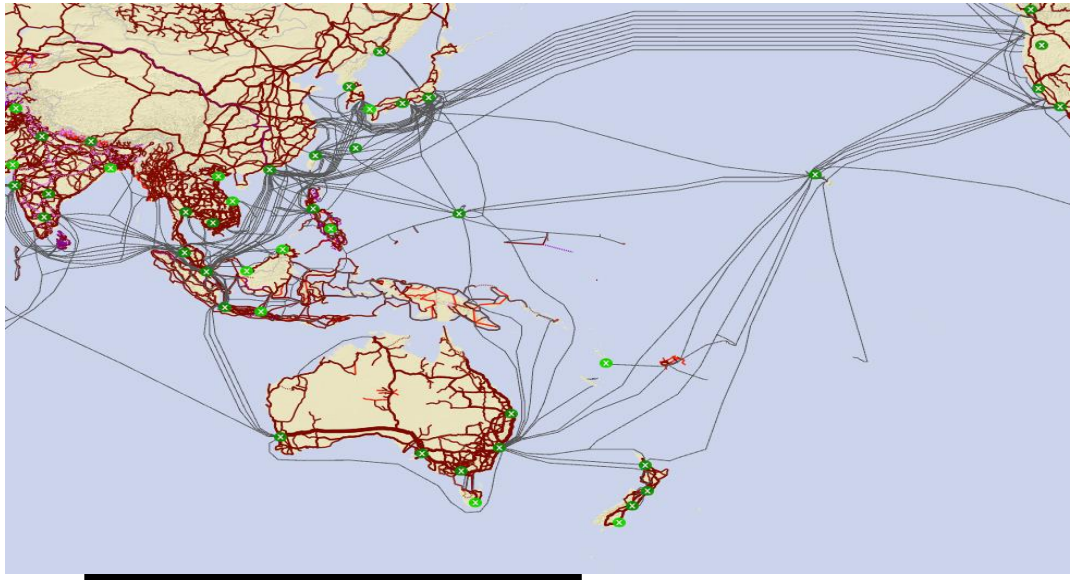




**Percentage of individuals using the Internet, by region and development status, 2019**

Source: https://itu.foleon.com/itu/measuring-digital-development/internet-use/

# Regional Background

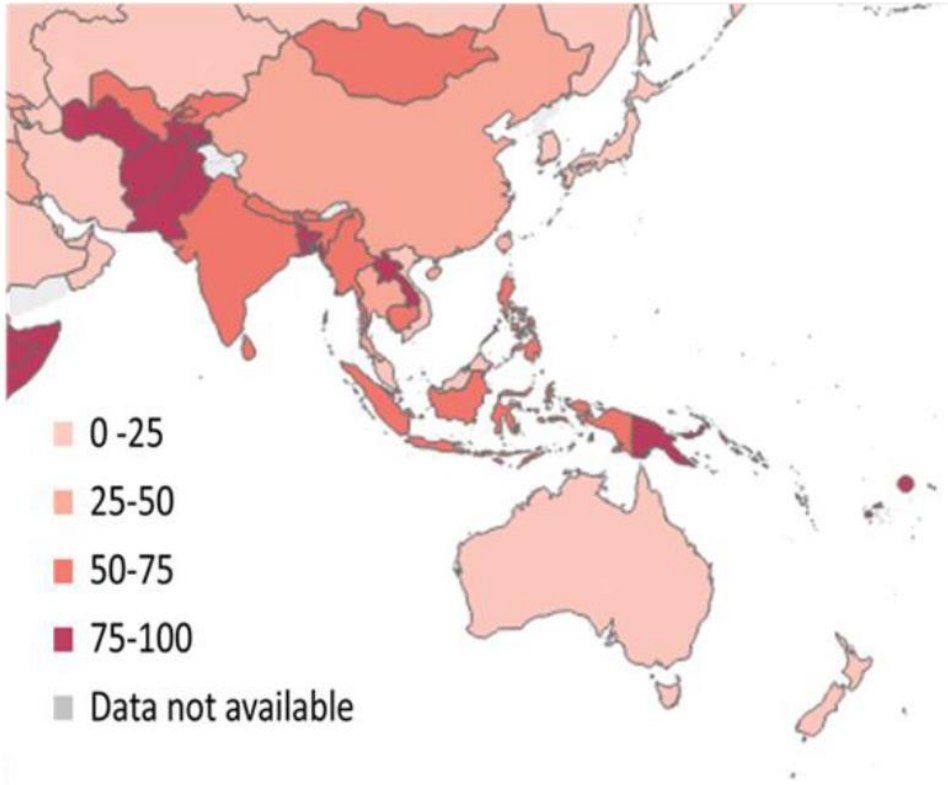


**SUMMARY - Distance (km)**

| AFR | AMS | ARB |
|---|---|---|
| 326.063 | 385.852 | 189.516 |
| Operators:93 | Operators:63 | Operators:41 |
| **ASP** | **CIS** | **EUR** |
| 812.666 | 385.852 | 444.818 |
| Operators:85 | Operators:36 | Operators:79 |

Source: https://www.itu.int/en/ITU-D/Technology/Pages/InteractiveTransmissionMaps.aspx



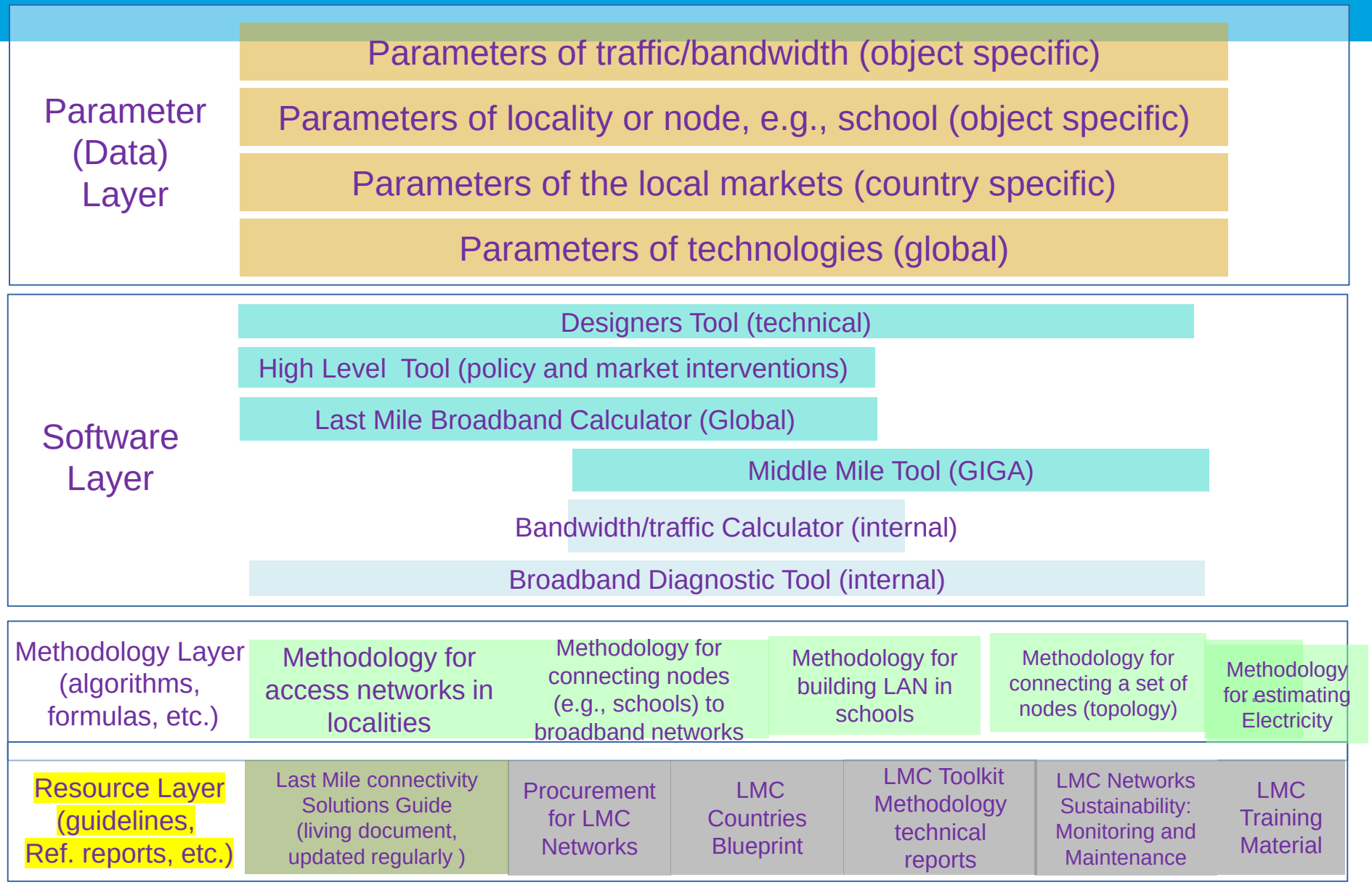

**Percentage of individuals using the Internet**
**Source: ITU**

# Introduction

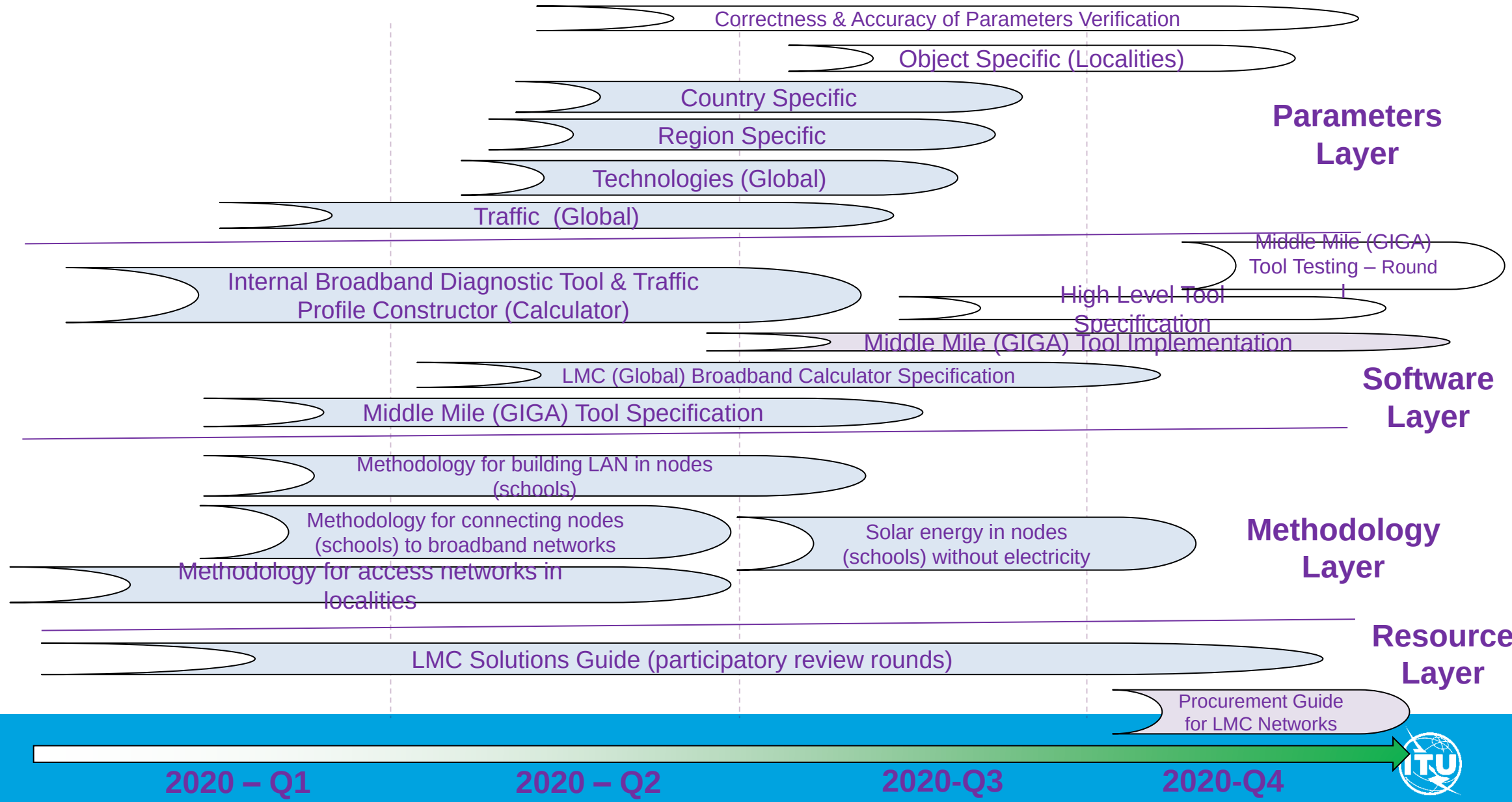
- LMC toolkit provides tools and support to decision makers, network designers or infrastructure owners, for selecting and implementing appropriate technology, business and regulatory connectivity solutions

- The Last Mile Connectivity Toolkit is a set of methodologies, software tools, parameters (data), reports and capacity building materials for selecting and implementing  last mile connectivity solutions
  - Includes suggestions for technical solutions, estimation of cost, investment, return on investment, duration, etc.

# Overall architecture of the Last Mile Connectivity Toolkit



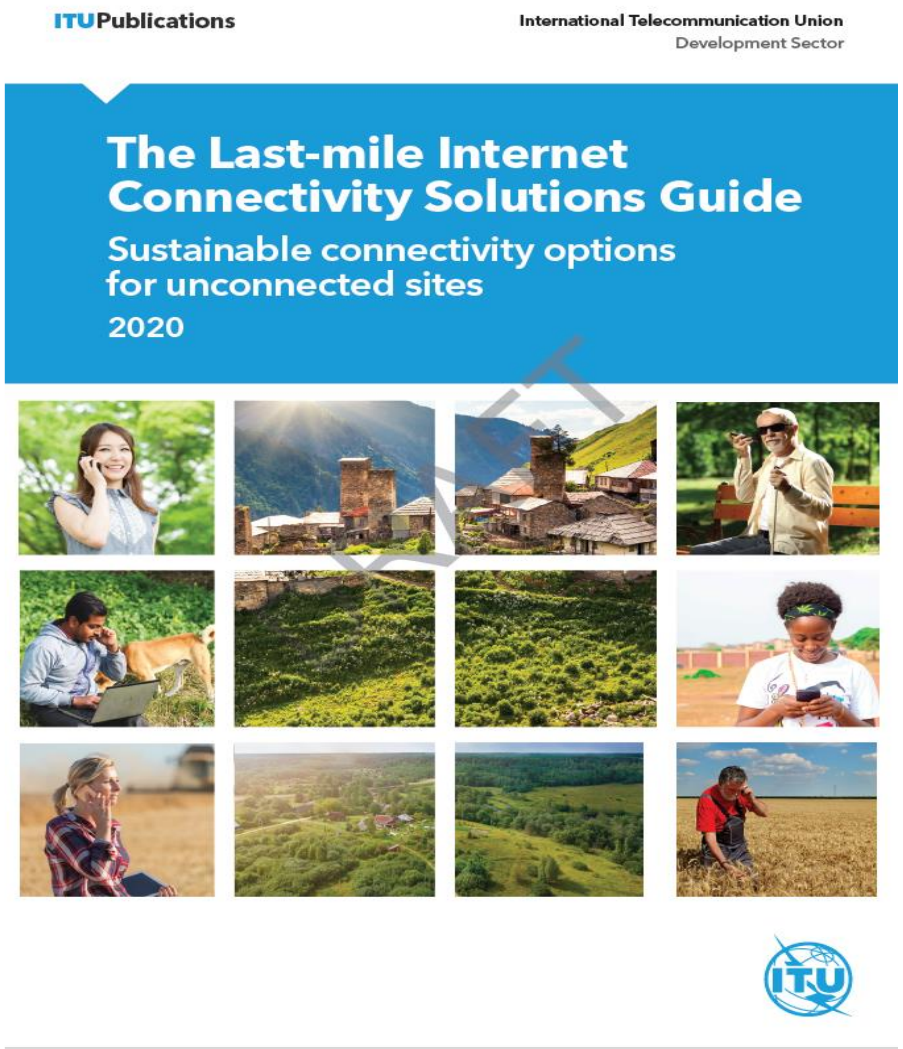
# Last Mile Connectivity Toolkit Implementation Status - 2020



# Resources

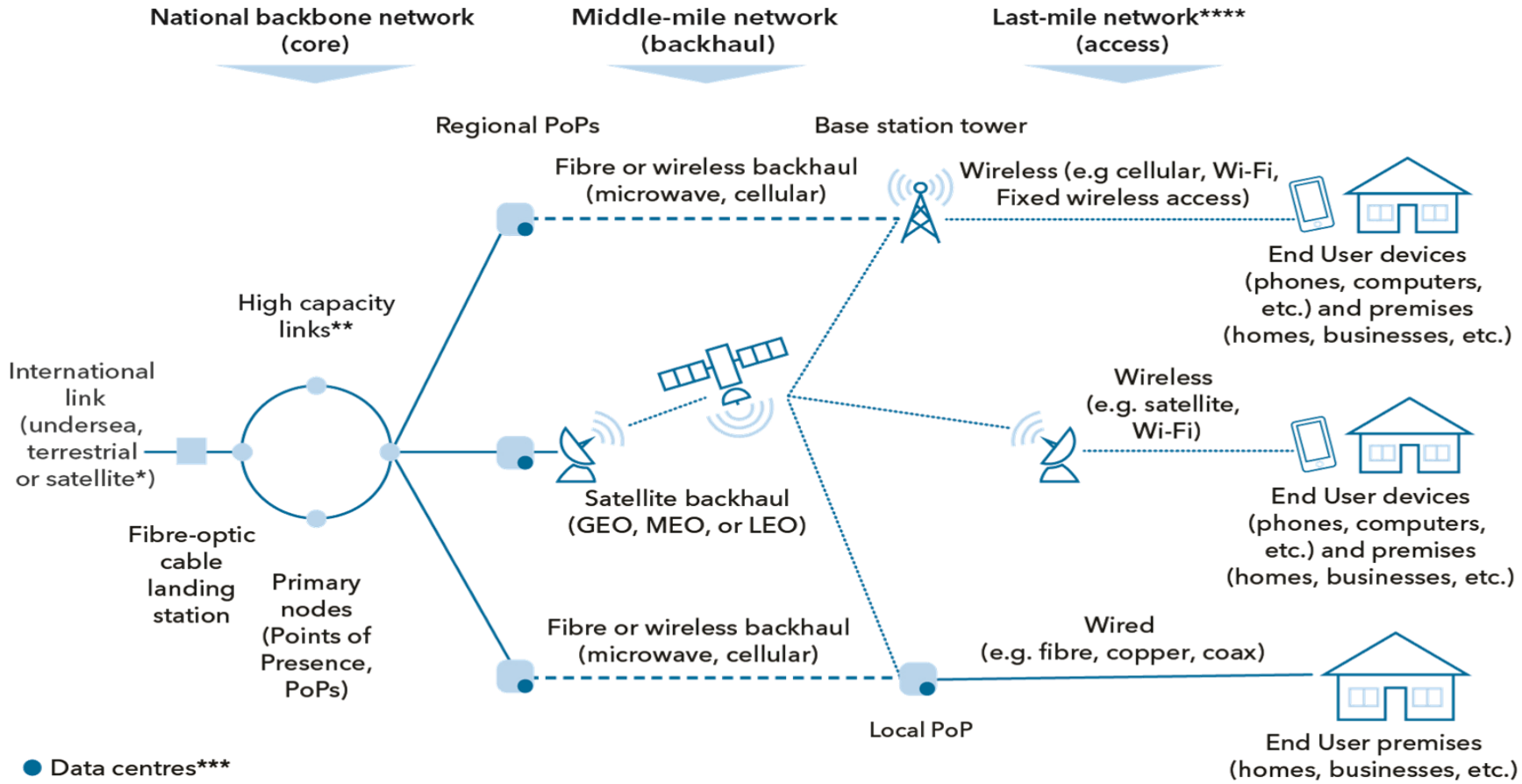
- Launched: December 2020
- https://www.itu.int/en/ITU-D/Technology/Pages/LMC/LMC-Home.aspx

  - Procurement Guide
  - Q1 2021



# Introduction: Definitions – Describing a Telecommunications Network

**Figure 2: Telecommunications network components supporting last-mile interventions in developing countries**




Source: Authors, adapted from various sources

Notes: Not exhaustive, for illustrative purposes and some segments are interchangeable further, particularly in the last-mile; *In few country cases, satellite continues to be the main, or only, source of international connectivity; ** These are predominantly fiber optic links (terrestrial and undersea) but in few country cases, national backbone networks utilize wireless microwave and satellite; *** Data centers can be placed in various parts of the network, depending on the need to aggregate data (such as in core networks, or place data as close to end users as possible (such as in middle mile and last-mile networks); **** The technologies listed for the last mile are not exhaustive.

# Steps in the Solutions Guide

**Step 1:**

**Identify digitally unconnected (and underserved) geographies**

**1a –** Understand background challenges in mapping access and adoption
**1b –** Select a top-down and/or bottom-up mapping approach
**1c –** Map key elements: network infrastructure assets, potential demand and financial viability, and constraints on technology options

**Step 2:**

**Review options from existing solutions**

**2a –** Review the case study database of last-mile connectivity solutions
**2b –** Utilize the categorization/typology of interventions
**2c –** Understand the main characteristics of, and trade-offs between, different interventions

**Step 3:**

**Select sustainable solutions by matching viability subject to constraints**

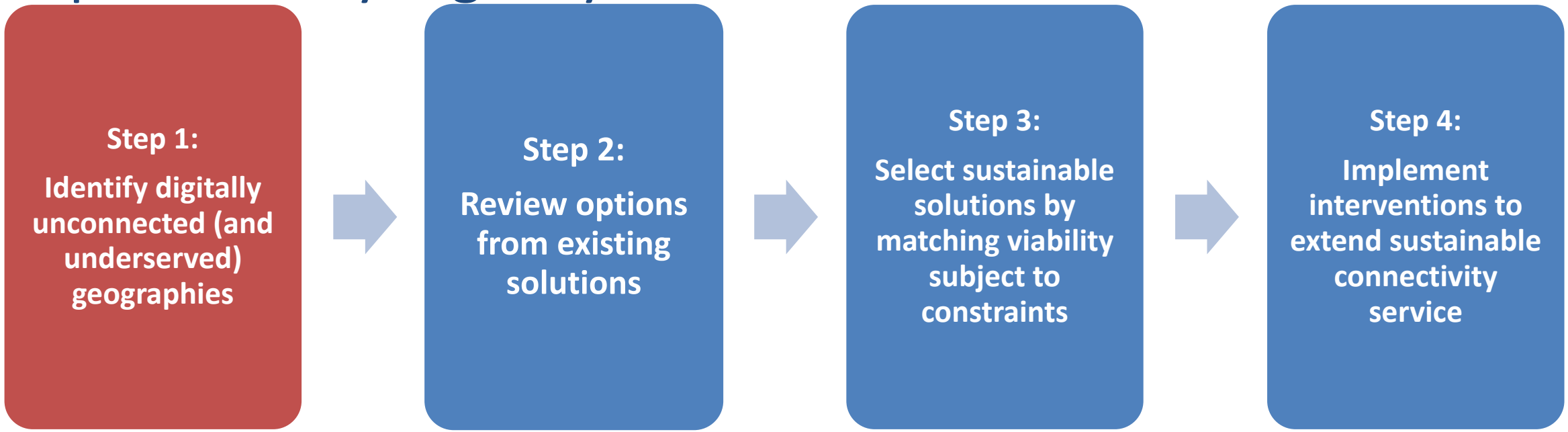
**3a –** Select an affordable last-mile connectivity solution
**3b –** Identify the components of an appropriate last-mile connectivity solution
**3c –** Draw up the decision matrix for feasible solutions
**3d –** Adopt additional tools to assess solutions

**Step 4:**

**Implement interventions to extend sustainable connectivity service**

**4a –** Options for intervention – Introduction
**4b –** Options for intervention – Market efficiency actions
**4c –** Options for intervention – One-time financing (smart subsidy)
**4d –** Options for intervention – Recurring financing / subsidy
**4e –** Examples of options (from case study submissions)

# Step 1: Identify Digitally Unconnected Communities



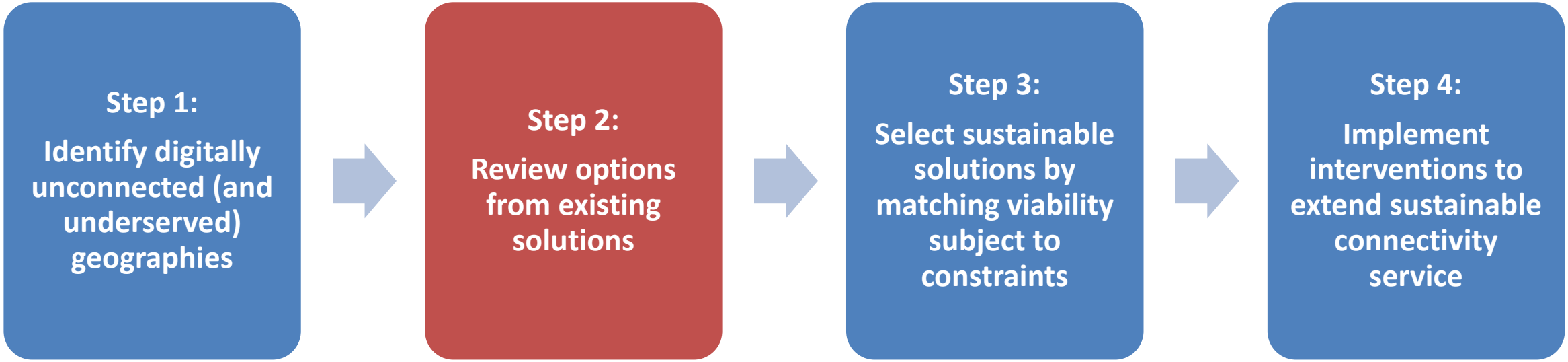

**Step 1 activities to identify digitally unconnected (and underserved) geographies:**

1a – Understand background challenges in mapping access and adoption

1b – Select a top-down and/or bottom-up mapping approach

1c – Map key elements: network infrastructure assets, potential demand and financial viability, and constraints on technology options

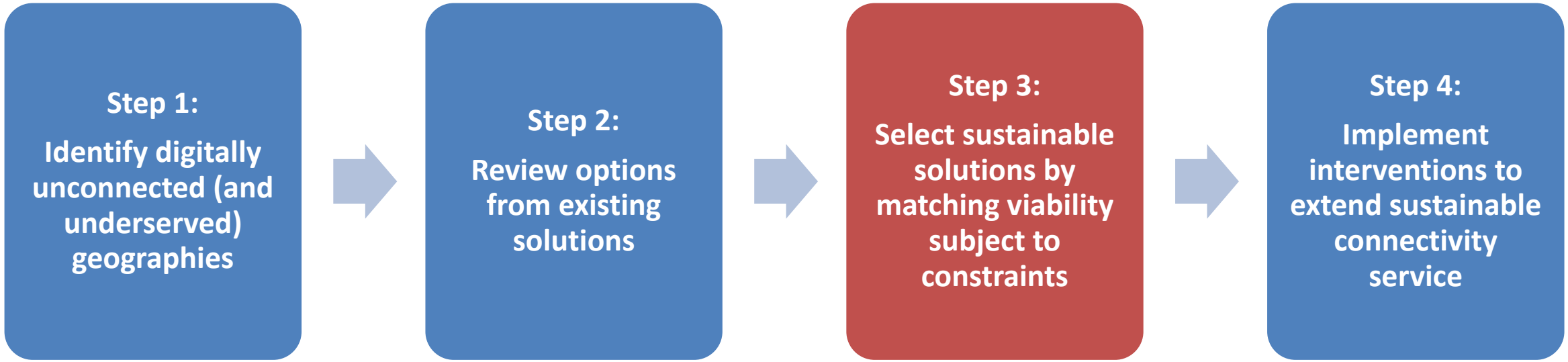
# Step 2: Review options from the classification of existing solutions




**Step 2 activities to review the range and classification of existing solutions:**

2a – Review the case study database of last-mile connectivity solutions
2b – Utilize the categorization/typology of interventions
2c – Understand the main characteristics of, and trade-offs between, different interventions

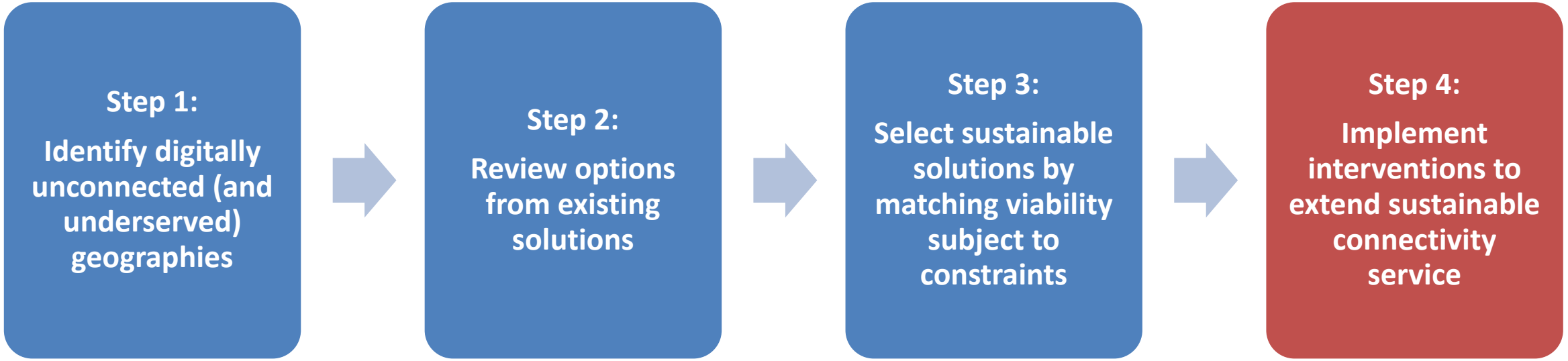
# Step 3: Select Sustainable Solutions by Matching Viability Subject to Constraints




**Step 3 activities to select sustainable solutions by matching viability subject to constraints:**

**3a –** Select an affordable last-mile connectivity solution
**3b –** Identify the components of an appropriate last-mile connectivity solution
**3c –** Draw up the decision matrix for feasible solutions
**3d –** Consider additional tools to assess solutions

# Step 4: Implement interventions to extend affordable connectivity service

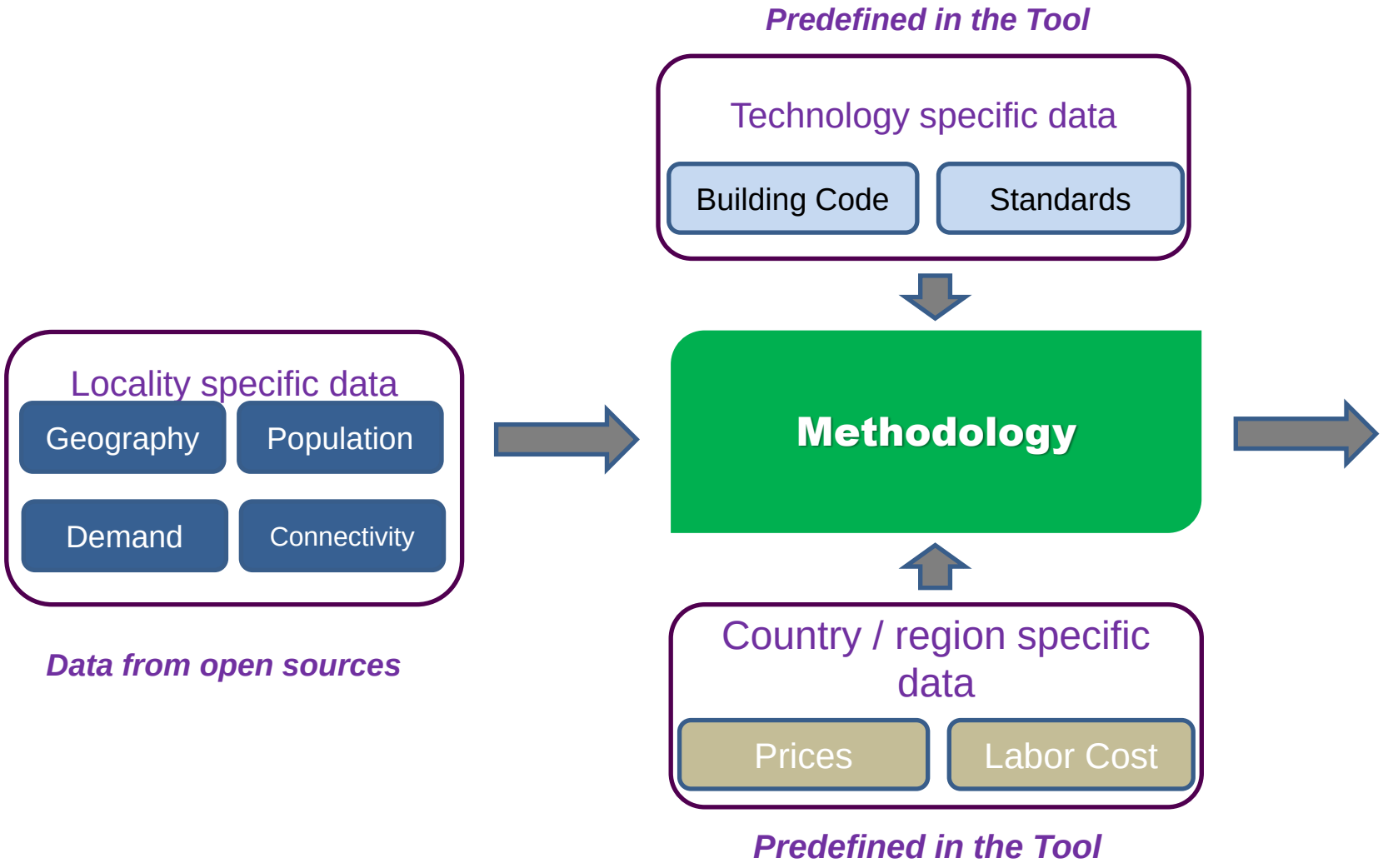



**Step 4 activities to implement interventions to extend sustainable connectivity service:**

**4a –** Options for intervention – Introduction
**4b –** Options for intervention – Market efficiency actions
**4c –** Options for intervention – One-time financing (smart subsidy)
**4d –** Options for intervention – Recurring financing/subsidy
**4e –** Examples of options (from case study submissions)

# Methodology

# Access networks (Last Mile) Methodology




| Option Name | CAPEX | OPEX | NPV |
|---|---|---|---|
| Ethernet FX + Ethernet TX + WiFi | … | … | … |
| DOCIS | … | … | … |
| Ethernet FX + ADSL2+ | … | … | … |
| PON + WiFi | … | … | … |
| …. | … | … | … |

# Electricity Methodology

Information about number of user's devices

OR

Information about external channel capacity

Total power required to provide power supply to active components of the school network, Watt

Number of workings hours per day

Efficiency of the battery

Daily demand on electric energy, Watt*hour

Insolation level

Efficiency of solar panel

Solar panel area


Number of required solar panels

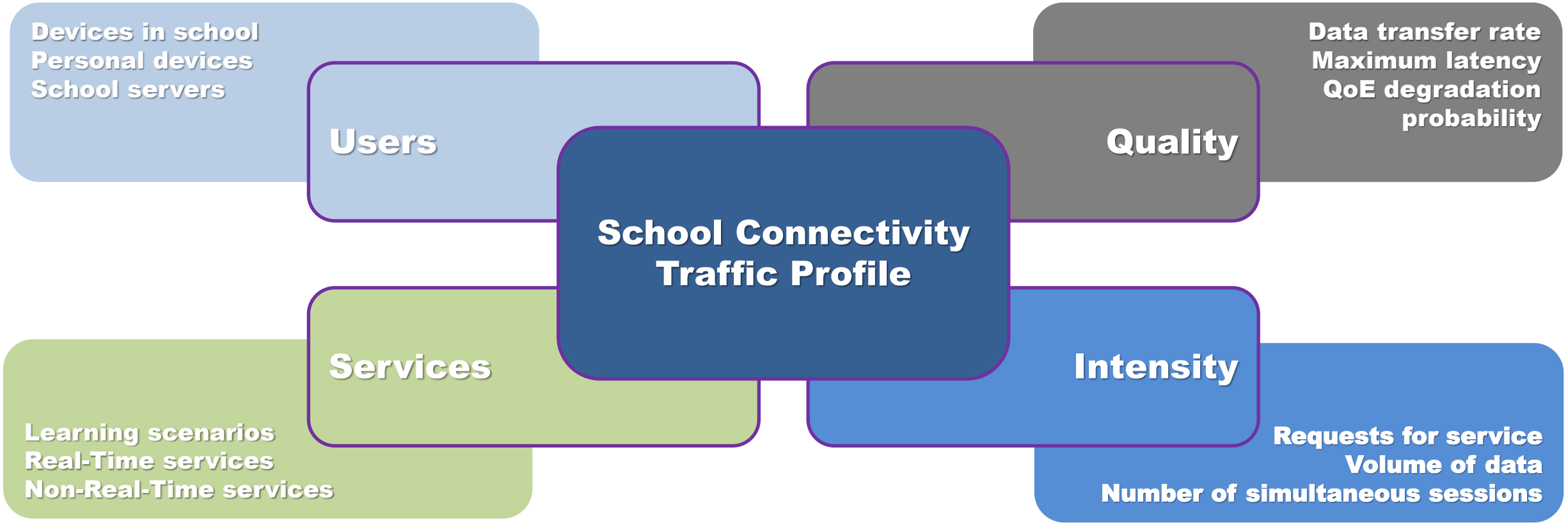
Nominal power of all solar panels

Characteristics of solar power plant (inverter) and number of batteries

Extra CAPEX & OPEX for schools without electricity

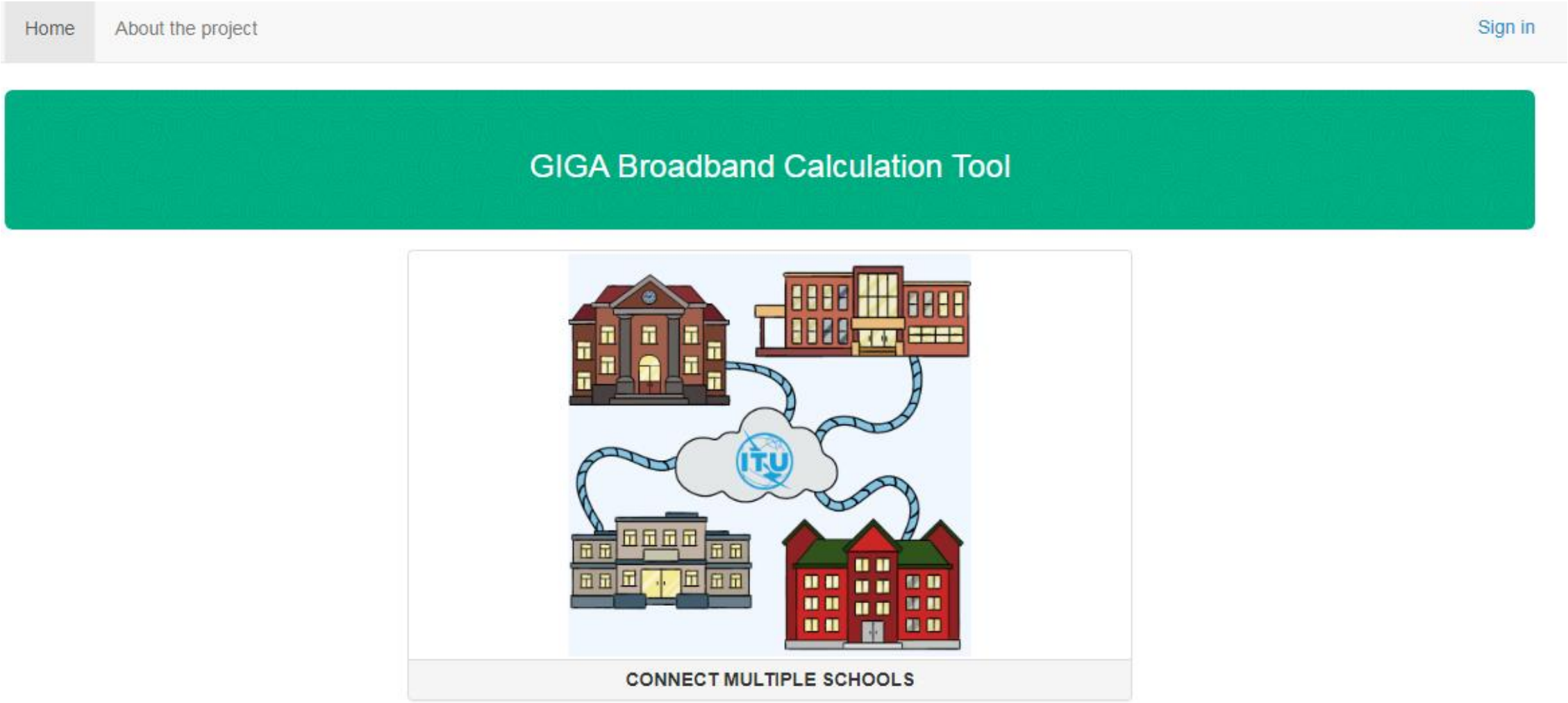
# School Connectivity Traffic Profile: Methodology

**School Connectivity Traffic Profile - a list of quality and intensity characteristics representing extent to which a school uses various Internet services**



# Software

# Middle Mile (GIGA) Tool: main screen



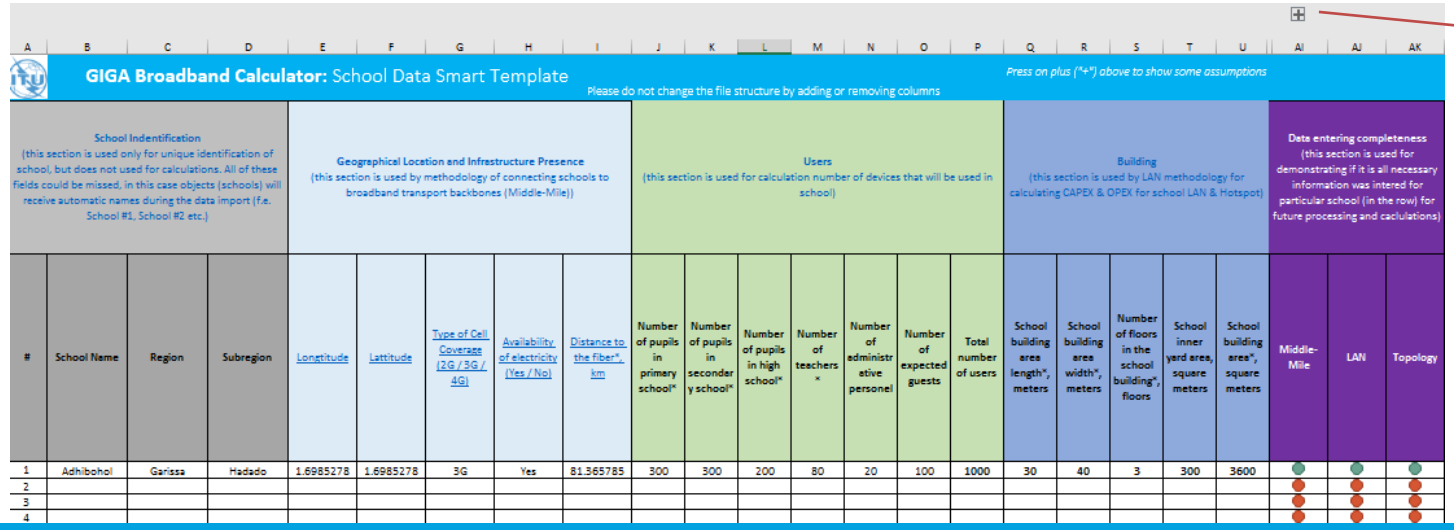

**Available at connectschools.online**

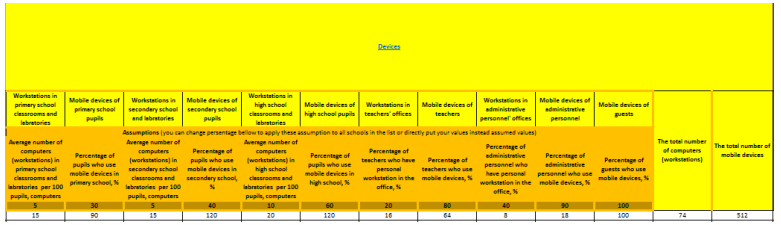
# Middle Mile (GIGA) : Smart Input Template

**GIGA Broadband Calculator:** School Data Smart Template

Please do not change the file structure by adding or removing columns

| School Indentification (this section is used only for unique identification of school, but does not used for calculations. All of these fields could be missed, in this case objects (schools) will receive automatic names during the data import (f.e. School #1, School #2 etc.) | | | | Geographical Location and Infrastructure Presence (this section is used by methodology of connecting schools to broadband transport backbones (Middle-Mile)) | | | | | Traffic (this section is used for giving direct instructions about required bandwidth) | Data entering completeness (this section is used for demonstrating if it is all necessary information was intered for particular school (in the row) for future processing | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| # | School Name | Region | Subregion | Longtitude | Lattitude | Type of Cell Coverage (2G / 3G / 4G) | Availability of electricity (Yes / No) | Distance to the fiber*, km | Required bandwidth*, Mbit/s | Middle-Mile | Topology |
| 1 | Adhibohol | Garissa | Hadado | 1.698527813 | 39.21347046 | 3G | Yes | 81.36 | 100 | | |
| 2 | | | | | | | | | | | |
| 3 | | | | | | | | | | | |




- ✓ Highlighting rows that could not be calculated (wrong or not enough data)
- ✓ Allowing to see assumptions made

# Middle Mile (GIGA) : Variables

Manage Project Variables

Download Project Variables Template

Upload New File

Supported file formats: XLSX

| | | |
|---|---|---|
| 1000 | Mbps | Communication channel capacity per single fiber |
| 0.02 | coeff | Road length deviation coefficient (relation of the road length to line of sight distance) |
| 0.01 | coeff | Coefficient of extra FOCL sections length of horizontal directional drilling, located at the crossings of roads |
| 0.1 | coeff | Coefficient of FOCL sections length requiring the construction of cable ducts |
| 0.9 | coeff | Coefficient of FOCL sections length requiring cable-laying machine |
| 2 | manholes | Number of cable manholes per one kilometer |
| 0.5 | couplings | Number of cable couplings per one kilometer |
| 0.1 | coeff | Coefficient of extra FOCL lenth taking into account the margin for laying and unpacking the cable |
| 0.05 | coeff | Coefficient of design cost work from the overall cost of FOCL |

**Personnel labor cost**

| | | |
|---|---|---|
| ELECTRICITY | | |
| 5 | USD/hour | Cost norms of installation, commissioning and maintenance of a solar power plant and solar panels |
| CELLULAR | | |

- ✓ More than 200 parameters are used for calculations
- ✓ More than 2,500 predefined values in database (global, regional and national variables)
- ✓ Default values are selected according to the country chosen (labor cost, cost of Internet etc.)
- ✓ Everything can be changed before the calculations, including assumptions and specific parameters

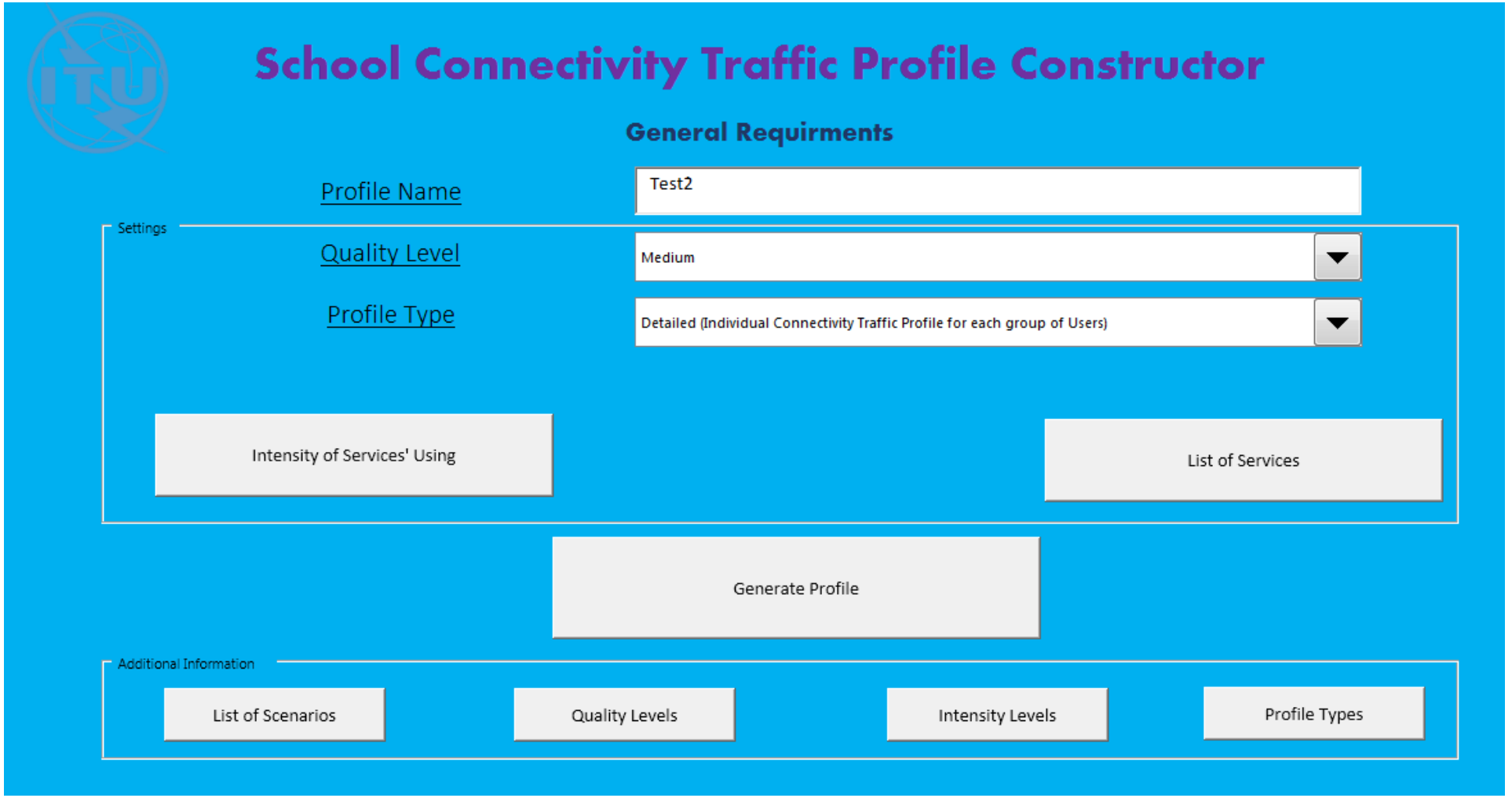
# Middle Mile (GIGA) : Smart Output Template

| Input data | | | | Calculation Result | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| School Identification | | | | Broadband (Middle-Mile) Connection | | | | | | | |
| | | | | Technology of Broadband Connection | | | | | | | |
| | | | | Fiber Optic | | | Microwave Link | | | Satellite | |
| # | School Name | Region | Subregion | CAPEX, USD | OPEX, USD per year | INCOME, USD per year | CAPEX, USD | OPEX, USD per year | INCOME, USD per year | CAPEX, USD | OPEX, USD per year |
| 1 | Kabarbarma | Eldoret | Baringo Central | 10 453.09 | 876.54 | 814.31 | 4 998.35 | 1 075.35 | 20.24 | 12 298.23 | 36 996.24 |
| 2 | Kabochony | Eldoret | Baringo Central | 42 08 | | | | | | | |
| 3 | Kapkiai | Eldoret | Baringo Central | 48 59 | | | | | | | |
| 4 | Kapkomoi | Eldoret | Baringo Central | 36 18 | | | | | | | |

| Calculation Result | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Broadband (Middle-Mile) Connection | | | | | | | | | |
| Recommended technology | | | | | | | | | |
| Based on maximum NPV (5-years) | Based on minimal cost of ownership (5-years) | Minimal 5-years cost of ownership, USD | Minimal 10-years cost of ownership, USD | Minimal 15-years cost of ownership, USD | Minimal 20-years cost of ownership, USD | Maximum 5-years NPV, USD | Maximum 10-years NPV, USD | Maximum 15-years NPV, USD | Maximum 20-years NPV, USD |
| Microwave | Microwave | Microwave 10375.1 | Microwave 15751.85 | Microwave 21128.6 | Microwave 26505.35 | Microwave -8920.3 | Fiber Optic -10983.92 | Fiber Optic -11195.99 | Fiber Optic -11378.92 |
| Microwave | Microwave | Microwave 10237.25 | Microwave 15476.15 | Microwave 20715.05 | Microwave 25953.95 | Microwave -8564.94 | Microwave -13183.16 | Microwave -16452.92 | Fiber Optic -13251.87 |
| Microwave | Microwave | Microwave 14979.18 | Microwave 21553.58 | Microwave 28127.98 | Microwave 34702.38 | Microwave -12908.04 | Microwave -18739.12 | Fiber Optic -19956.74 | Fiber Optic -12905.73 |
| Microwave | Microwave | Microwave 10327 | Microwave 15655.65 | Microwave 20984.3 | Microwave 26312.95 | Microwave -8683.26 | Microwave -13454.68 | Microwave -16832.9 | Fiber Optic -13416.36 |
| Fiber Optic | Fiber Optic | Fiber Optic 7511.82 | Fiber Optic 11122.07 | Fiber Optic 14732.32 | Fiber Optic 18342.57 | Fiber Optic -5597.35 | Fiber Optic -7793.13 | Fiber Optic -9347.78 | Fiber Optic -10688.82 |
| Microwave | Microwave | Microwave 10331 | Microwave 15663.65 | Microwave 20996.3 | Microwave 26328.95 | Microwave -8669.84 | Microwave -13423.89 | Microwave -16789.81 | Fiber Optic -13451.74 |
| Fiber Optic | Fiber Optic | Fiber Optic 12554.74 | Fiber Optic 19150.44 | Fiber Optic 25746.14 | Fiber Optic 32341.84 | Fiber Optic -9303.02 | Fiber Optic -13632.98 | Fiber Optic -16698.65 | Fiber Optic -19343.11 |

- ✓ Making decision about recommended technology within the template
- ✓ Allowing to see all input data and assumptions made
- ✓ Containing calculations for 5, 10, 15 and 20 years

# Internal Tools: Traffic Profile Constructor



# School Connectivity Traffic Profile: Examples

| Input data | | | | | | | Calculation Result | | |
|---|---|---|---|---|---|---|---|---|---|
| School Identification | | Users | Devices | | | | Broadband (Middle-Mile) Connection | | |
| # | School Name | Total number of users | Total number of pupils | Number of teachers | Number of administrative personel | Number of expected guests | Basic Profile - Required Bandwidth, Mbps | Intermediate Profile - Required Bandwidth, Mbps | Advanced Profile - Required Bandwidth, Mbps |
| 1 | School 1 | 100 | 90 | 5 | 3 | 2 | 32.25 | 241.00 | 514.50 |
| 2 | School 2 | 200 | 180 | 10 | 6 | 4 | 35.00 | 304.38 | 580.31 |
| 3 | School 3 | 300 | 270 | 15 | 9 | 6 | 38.25 | 341.00 | 640.31 |
| 4 | School 4 | 400 | 360 | 20 | 12 | 8 | 40.00 | 375.88 | 694.50 |
| 5 | School 5 | 500 | 450 | 25 | 15 | 10 | 41.50 | 420.38 | 737.81 |
| 6 | School 6 | 600 | 540 | 30 | 18 | 12 | 44.50 | 454.88 | 770.81 |
| 7 | School 7 | 700 | 630 | 35 | 21 | 14 | 46.00 | 486.38 | 816.19 |
| 8 | School 8 | 800 | 720 | 40 | 24 | 16 | 47.75 | 505.00 | 849.19 |
| 9 | School 9 | 900 | 810 | 45 | 27 | 18 | 49.00 | 538.50 | 898.50 |
| 10 | School 10 | 1000 | 900 | 50 | 30 | 20 | 51.25 | 563.25 | 927.56 |

# Parameters

# Broadband Diagnostic Toolkit:
# List of Parameters - General Overview

| Class (Group) of Parameters | Scale of Parameters | | | | Number of Parameters | Number of values for justification |
|---|---|---|---|---|---|---|
| | Global | Regional | National | Specific | | |
| Economical & Geographical Parameters | 0 | 2 | 10 | 29 | 41 | 2596 |
| Parameters of Services | 4 | 0 | 0 | 0 | 4 | 44 |
| Parameters of equipment & materials, including cost, normative labor for installation & operation and technical charactreristics | 105 | 0 | 0 | 0 | 105 | 215 |
| Labor cost | 0 | 44 | 0 | 0 | 44 | 792 |
| Total | 109 | 46 | 10 | 29 | 194 | 3647 |

# School Connectivity Traffic Profile: Values used

| # | Name of Service* | Quality Level | | | | | |
|---|---|---|---|---|---|---|---|
| | | Low | | Medium | | High | |
| | | Maximum Latency**, ms | Data Transfer Rate (for one session), Mbit/s | Maximum Latency**, ms | Data Transfer Rate (for one session), Mbit/s | Maximum Latency**, ms | Data Transfer Rate (for one session), Mbit/s |
| 1 | Streaming video, including interactive online TV, live-stream trainings, individualized live video instructions etc. | 1000 | 2 | 500 | 4 | 250 | 10 |
| 2 | Services for group & individual communication, including webinars, conferences, meetings, tutoring, etc. | 400 | 1 | 200 | 1,5 | 100 | 2,25 |
| 3 | Online virtual simulators, educational online games, etc. | 400 | 0,5 | 200 | 0,75 | 100 | 1,125 |
| 4 | Services for group work (virtual boards, online graphics, etc.) | 400 | 1 | 200 | 1,5 | 100 | 2,25 |
| 5 | Other Real Time Traffic Services | 1000 | 0,5 | 500 | 0,75 | 250 | 1,125 |
| 6 | Recorded educational clips, video instructions, trainings, Individualized recorded video, multimedia courses etc. | 1000 | 0,75 | 500 | 1,125 | 250 | 1,68 |
| 7 | Learning management systems, including libraries, repositories, databases, educational web-services, services for storing information etc. | 1500 | 0,5 | 750 | 0,75 | 375 | 1,125 |
| 8 | Web-serfing, Search engines, bookmarking services, etc. E-mail, FTP and other classic services | 1500 | 0,5 | 750 | 0,75 | 375 | 1,125 |
| 9 | Discussion boards, Social media & networks, forums etc. | 1500 | 0,5 | 750 | 0,75 | 375 | 1,125 |
| 10 | Calendars and organizers, including lessons planning. Government e-portal access. Reporting Services etc. | 1500 | 0,25 | 750 | 0,375 | 375 | 0,5625 |
| 11 | Other Non-Real Time Traffic Services | 1500 | 0,25 | 750 | 0,375 | 375 | 0,5625 |

The data indicated in Table are formed on the basis of the analysis of the values determined in the ITU-T Recommendations Y.1540 (p.17-20), Y.1541 (p. 7-9, 11, 20,21), Y.1920 (p. 14, 15), Y.2113 (p.16), Y.1542 (p.12-17), G.114 (p. 1, 4), G. 1010 (p. 8, 9), G. 1020 (p. 8), the ITU-T Recommendations Y.3042 (p. 9), G. 1010 (p.9-11) and also in documents Quality of service regulation (p. 43, 49, p. 86) and ETSI EG 202 057-4 (p. 30, 31).

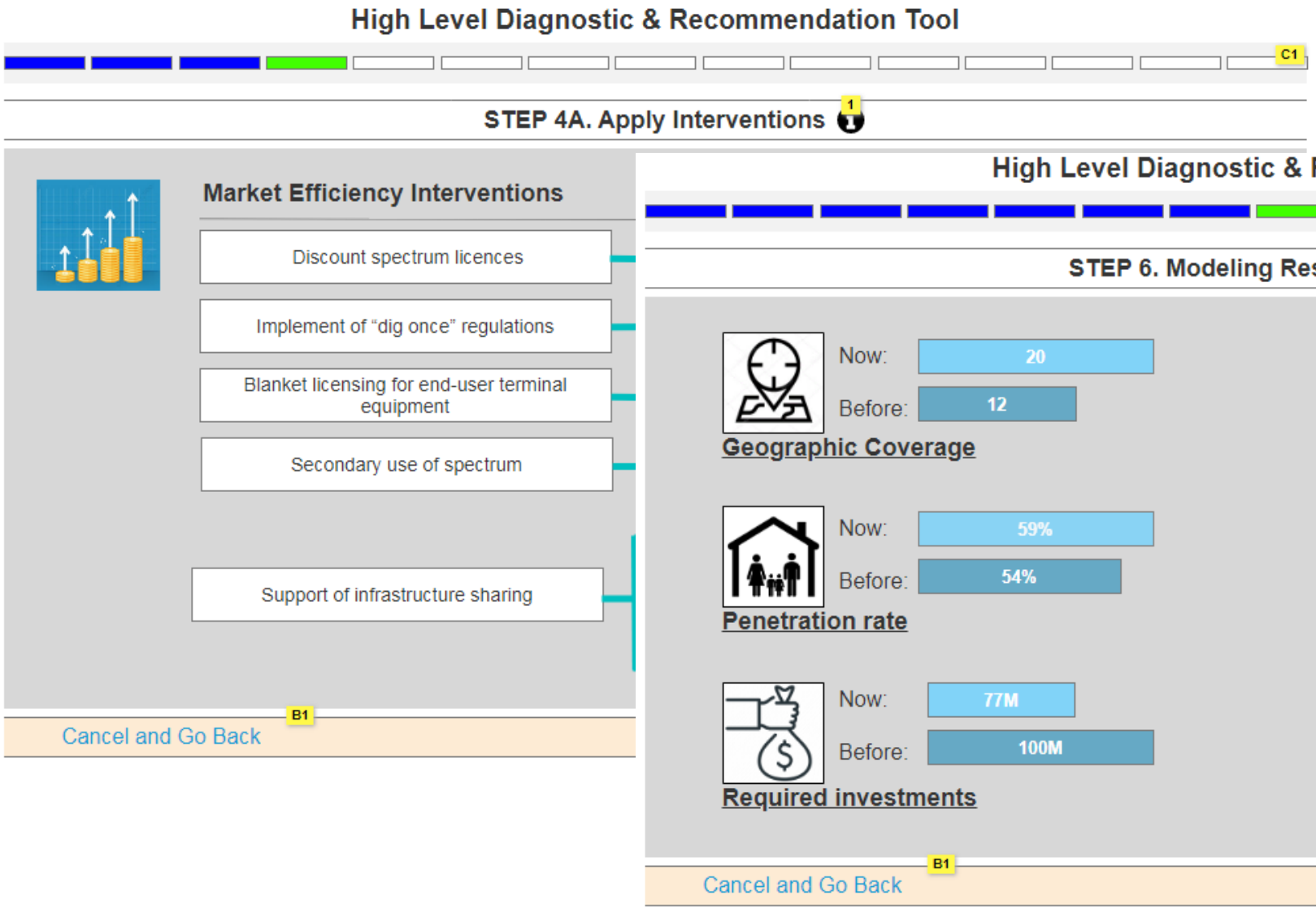
# School Connectivity Traffic Profile: Values used

| # | Name of Service* | Intensity Level | | | | | |
|---|---|---|---|---|---|---|---|
| | | Low | | Medium | | High | |
| | | Intensity of Using (for one user), requests / hour | Volume of Data (per session), MB | Intensity of Using (for one user), requests / hour | Volume of Data (per session), MB | Intensity of Using (for one user), requests / hour | Volume of Data (per session), MB |
| 1 | Streaming video, including interactive online TV, live-stream trainings, individualized live video instructions etc. | 0,21 | 400 | 0,42 | 275 | 0,63 | 412,5 |
| 2 | Services for group & individual communication, including webinars, conferences, meetings, tutoring, etc. | 0,002 | 150 | 0,004 | 135 | 0,006 | 202,5 |
| 3 | Online virtual simulators, educational online games, etc. | 0,004 | 50 | 0,008 | 100 | 0,012 | 150 |
| 4 | Services for group work (virtual boards, online graphics, etc.) | 0,0025 | 25 | 0,005 | 50 | 0,0075 | 75 |
| 5 | Other Real Time Traffic Services | 0,0025 | 100 | 0,005 | 100 | 0,0075 | 150 |
| 6 | Recorded educational clips, video instructions, trainings, Individualized recorded video, multimedia courses etc. | 0,00125 | 250 | 0,0025 | 250 | 0,00375 | 375 |
| 7 | Learning management systems, including libraries, repositories, databases, educational web-services, services for storing information | 0,04 | 5 | 0,08 | 5 | 0,12 | 7,5 |
| 8 | Web-serfing, Search engines, bookmarking services, etc. E-mail, FTP and other classic services | 0,17 | 2.5 | 0,34 | 5 | 0,51 | 7,5 |
| 9 | Discussion boards, Social media & networks, forums etc. | 0,0875 | 2.5 | 0,175 | 1,5 | 0,2625 | 2,25 |
| 10 | Calendars and organizers, including lessons planning. Government e-portal access. Reporting Services etc. | 0,1 | 2.5 | 0,2 | 1,5 | 0,3 | 2,25 |
| 11 | Other Non-Real Time Traffic Services | 0,1 | 5 | 0,2 | 1,5 | 0,3 | 2,25 |

The data indicated in Table are formed based on real experiments and traffic measurements for real school in Odessa, Ukraine. The school is connected to the Internet through an optical channel with bandwidth of 50 Mbps. The number of users is 385 people (350 students and 35 school employees)

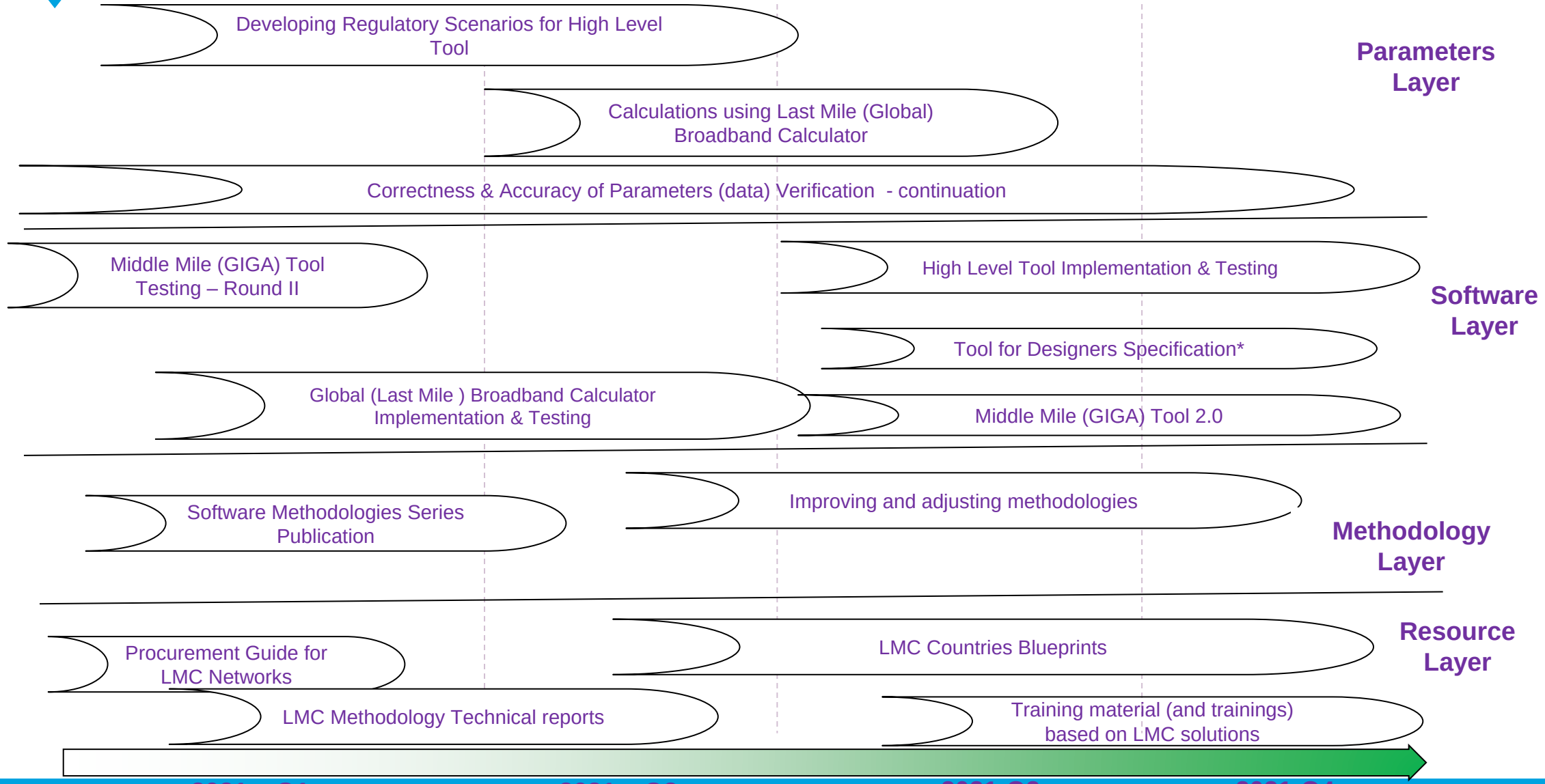
# Going Ahead

# Upcoming Software: High Level Tool



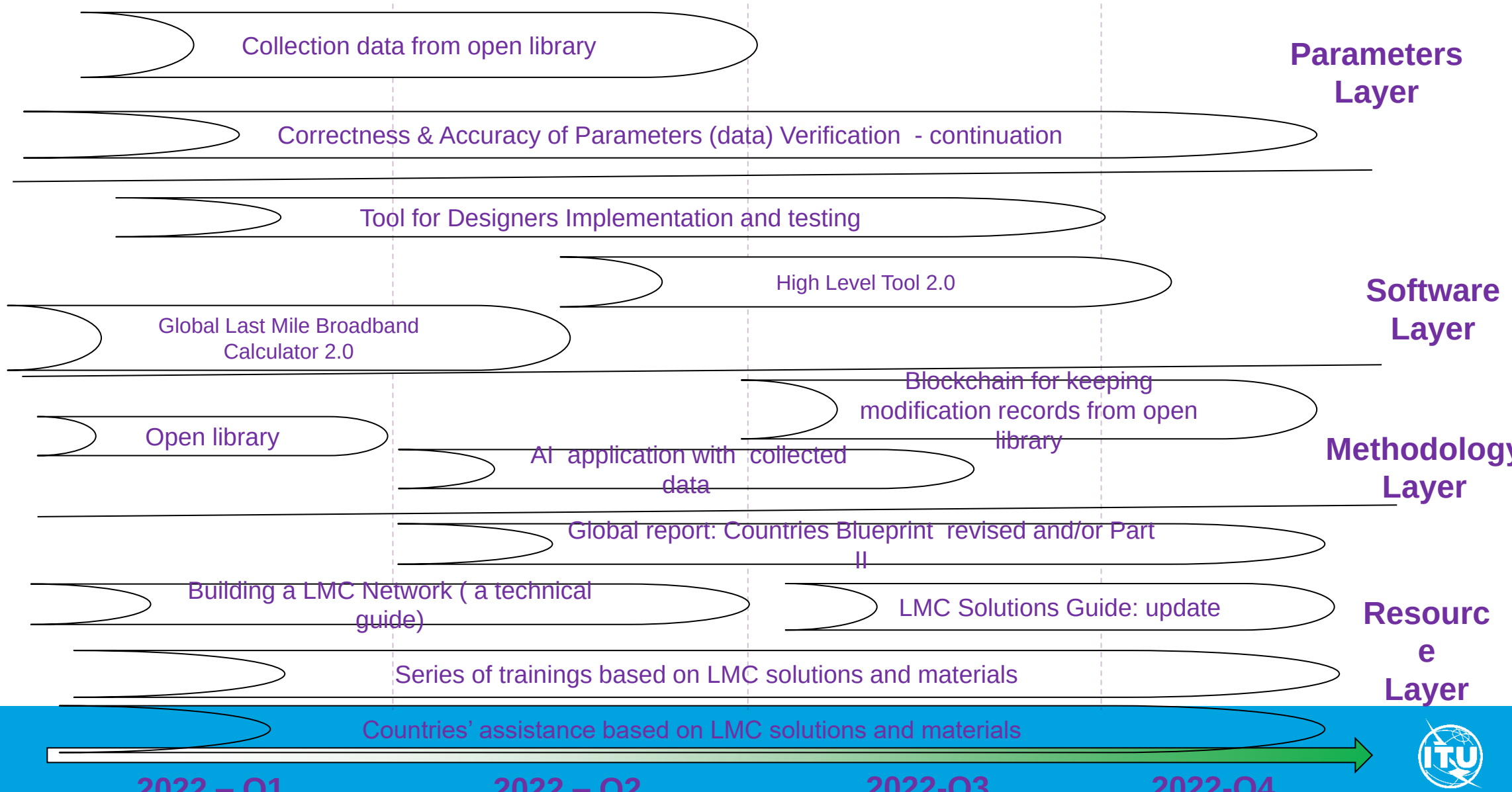

The main purpose of the tool – is to demonstrate (in gamified way with high level of visualization) to the High Level decision makers the key factors that could influent into the process of telecom networks deployment.

# Last Mile Connectivity Toolkit Implementation Status - 2021




* The tool will be implemented in 2022

# Last Mile Connectivity Toolkit Implementation Plan - 2022



# Usage Scenarios

| ITU | Administrations and sector members | Development partners |
| --- | --- | --- |
| Integrated into Giga and Smart village/Smart islands. | Can use on their own for national/business connectivity planning | Can use it for their development projects in partnership with ITU |

# Remain Connected with us!

**Linkedin URL:**
https://www.linkedin.com/company/itu-regional-officefor-asia-and-the-pacific/?viewAsMember=true

**Twitter Handle:**
@ITU_ASP (https://twitter.com/ITU_ASP)

# THANK YOU

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# Annex 2: Additional Resources for Mapping

## Network Infrastructure Mapping

**Fiber (Undersea & Terrestrial):**
ITU – Broadband Maps: https://itu.int/go/Maps
Telegeography – Submarine Cable Map: https://github.com/telegeography/www.submarinecablemap.com
African Terrestrial Fiber Optic Cable Mapping Project
The Connected Pacific

**Satellite coverage:**
SatBeams coverage maps and charts
LyngSat Maps
IntelSat Coverage Map
Iridium Coverage Map
Inmarsat Coverage Map

**Base stateion locations and coverage:**
GSMA - Mobile Coverage Maps
Open Telecom Data – Tower location (Various countries)
OpenCellID
OpenSignal

**Wi-Fi Coverage:**
Mozilla Location Service (MLS)

**Spectrum:**
Open Telecom Data - Spectrum allocations (Africa)

## Socio-Demographic, Environmental, Geographic Data:

**Population density:**
JRC's Global Human Settlement Layer population
WorldPop – University of Southampton
Landscan – Oak Ridge
CIESIN's Gridded Population of the World (GPW)
CIESIN / Facebook High Resolution Settlement Layer (HRSL) Map

**Electrification:**
Gridfinder
World Bank / Facebook Model

## Other Resources:

**References / How-to:**
World Bank – Broadband Mapping
Jon Brewer – Using GIS to Deliver Universal Broadband

**Modeling Radio Frequency Propagation**
SPLAT
CloudRF

# Annex 2: Additional Resources (Technical References, Policy, & Case Studies)

**Technical References**

**Networks**

Telecom Network Planning for evolving Network Architectures – Reference Manual
Wireless Networking in the Developing World
Building a Wireless Community Network in the Netherlands
Planning of Wireless Community Networks
ITU Infrastructure Portal
How to work with MNOs (UNHCR)
Community Networks through comics
Ericsson FWA Handbook
EU Comparison of wired and wireless broadband technologies

**Financing**

ICT Infrastructure business planning Solutions Guide 2019
EU Broadband Investment Guide

**Demand Side Issues**

NTIA Considerations for Digital Inclusion Efforts

**Policy and Regulatory Recommendations**

ICT Regulation Toolkit
A4AI Good Practices Database
Community Networks in Latin America
OECD Telecom Topics Reports
Dynamic Spectrum Alliance Regulations

**Other Resources:**

World Bank Broadband Strategies Solutions Guide
Digital Interoperable Building Blocks (Content, Applications and Services)
BCG Economics of Bringing Broadband to Rural US
US NTIA Resources
US NTIA Webinars
World Bank Cross-Sector Infrastructure Sharing Solutions Guide
World Bank Cloud Readiness Assessment Solutions Guide
The Solar Energy Handbook (Moving Energy Initiative)
NGO Guide to Energy Solutions (NetHope)
UNHCR Connectivity for Refugees

**Case Studies:**

LMC Case Studies Database
School Connectivity Projects Database
1WorldConnected
APC Report
Microsoft Airband Initiative
UNHCR Collaboration for Connectivity
EU Broadband Handbook
Satellite Impact Around the World (Global Satellite Coalition)

# Annex 2: Additional Reports Referenced and Consulted in the Literature Review

Collaborating for Connectivity (UNHCR, 2020)
Digital Access in Africa (Caribou Digital, 2019)
Connecting the Unconnected – Tackling the Challenge of Cost-Effective Broadband Internet in Rural Areas (Fraunhofer FIT, 2019)
Closing the Coverage Gap: How Innovation Can Drive Rural Connectivity (GSMA, 2019)
Becoming Broadband Ready – A Toolkit for Communities (Next Century Cities, 2019)
The Mobile Economy 2019 (GSMA, 2019)
Digital Dividend: Insights for Spectrum Decisions (ITU, 2018)
State of Mobile Internet Connectivity 2018 (GSMA, 2018)
Innovative Business Models for Expanding Fiber-Optic Networks and Closing the Access Gaps (World Bank, 2018)
Rural Connectivity Innovation Case Study: Using light sites to drive rural coverage – Huawei RuralStar and MTN Ghana (GSMA, 2018)
Community Networks in Latin America: Challenges, Regulations, and Solutions (Internet Society, 2018)
Global Information Society Watch 2018: Community Networks (APC and IDRC, 2018)
Rural Connectivity Innovation Case Study: Cellcard Cambodia (GSMA, 2018)
Powering Last-Mile Connectivity (Facebook / Bloomberg New Energy Finance, 2018)
Spectrum management principles, challenges and issues related to dynamic access to frequency bands by means of radio systems employing cognitive capabilities (ITU, 2017)
Evolving spectrum management tools to support development needs (ITU, 2017)
A Wireless Network Infrastructure Architecture for Rural Communities (Osahon & Emmanuel, 2017)
Closing the Access Gap: Innovation to Accelerate Universal Internet Adoption (USAID, 2017)
Bottom-up Connectivity Strategies (APC, 2019)
Last Mile Connectivity in Emerging Markets (Developing Telecoms, 2016)
Unlocking Rural Coverage (GSMA, 2016)
Business Models for the Last Billion: Market Approaches to Increasing Internet Connectivity (USAID, 2016)
Harnessing the Internet of Things for Global Development (ITU & Cisco, 2015)
Rural Coverage: Strategies for Sustainability (GSMA, 2015)
Benefits and Costs of the Infrastructure Targets for the Post-2015 Development Agenda Post-2015 Consensus (Copenhagen Consensus Center, 2014)
Computing for Rural Empowerment: Enabled by Last-Mile Telecommunications (Various, 2013)
Rural Telecommunications Infrastructure Selection Using the Analytic Network Process (Various, 2010)
Connectivity in Emerging Regions: The Need for Improved Technology and Business Models (CMU, 2007)
Improving affordability of telecommunications: cross-fertilization between the developed and the developing world (Claire Milne, 2006)
Community-Based Networks and Innovative Technologies: New Models to Serve and Empower the Poor (UNDP, 2005)