



Last Mile Connectivity Solution: Toolkit

Online
22 Feb 2021

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Scope

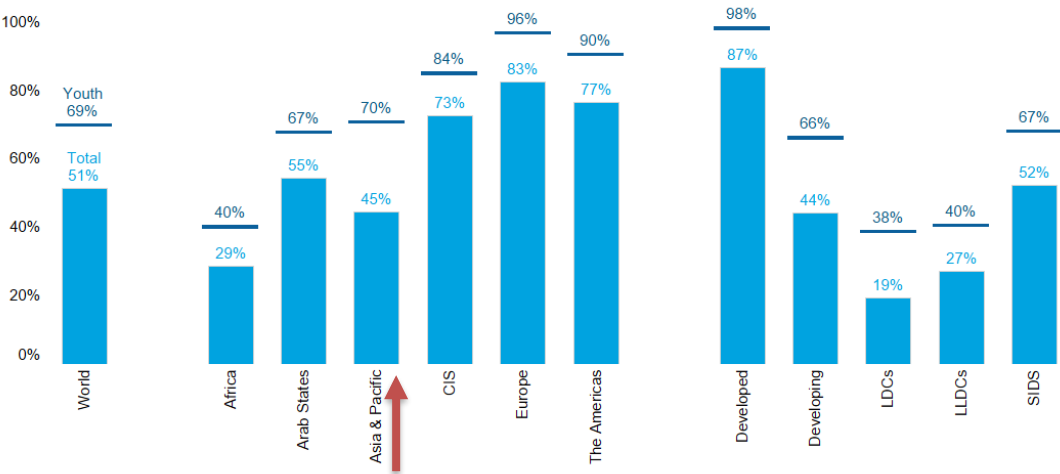
Why the requirement?

Toolkit

Going Ahead

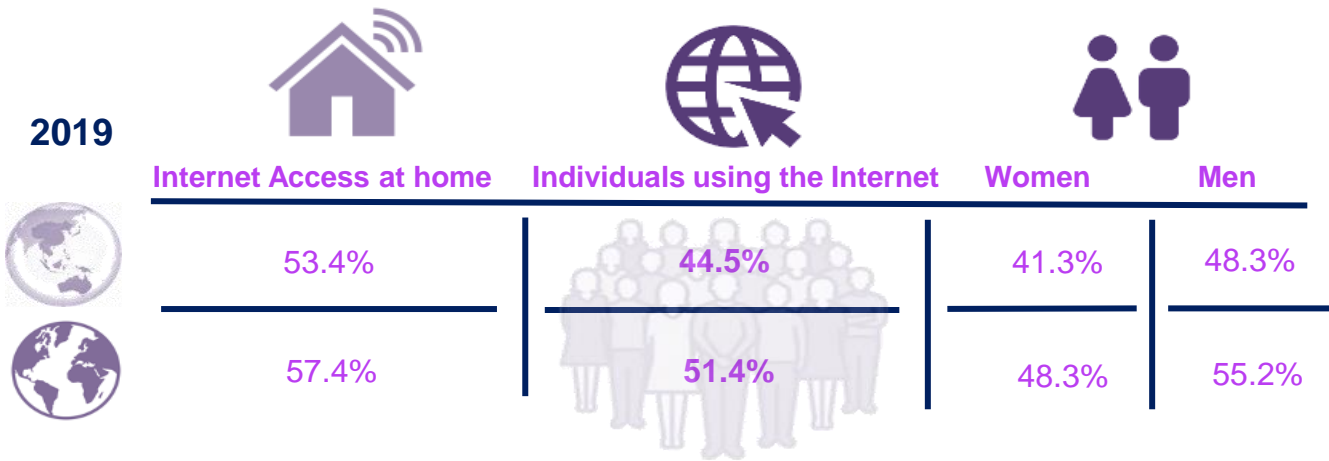
Regional Background

Percentage of individuals using the Internet, 2019*



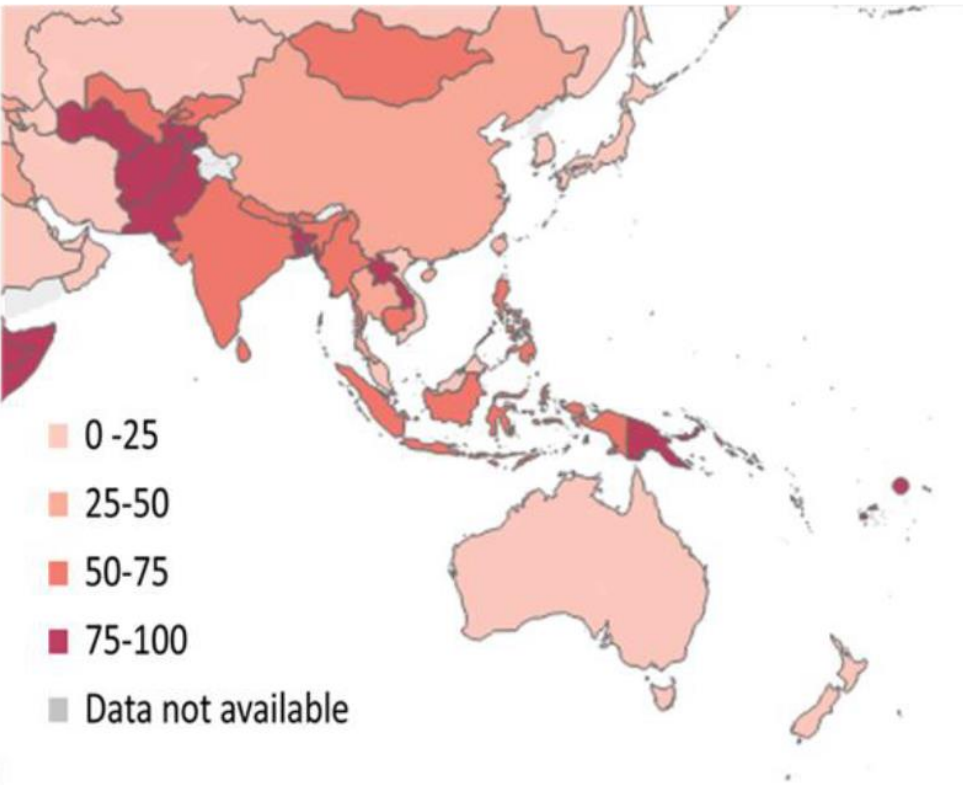
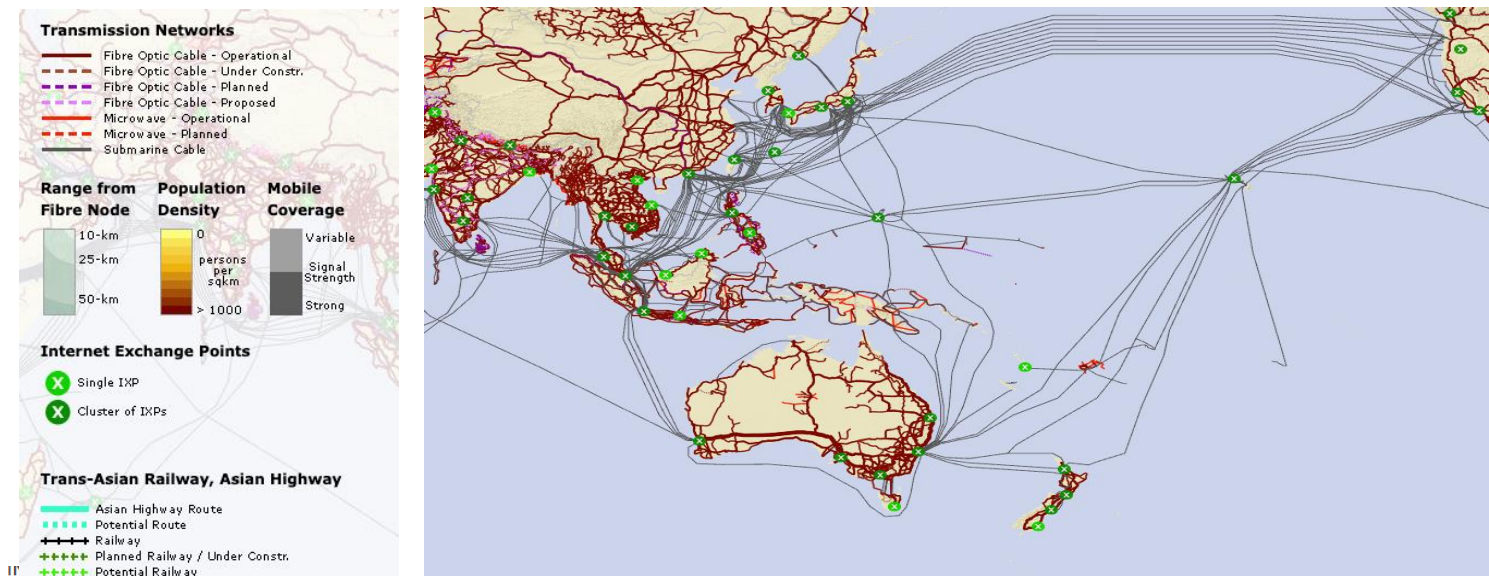
* ITU estimate. Source: ITU
 Note: youth means 15-24 year old individuals using the Internet as a percentage of the total population aged 15 to 24 years.

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



Percentage of individuals using the Internet
Source: ITU

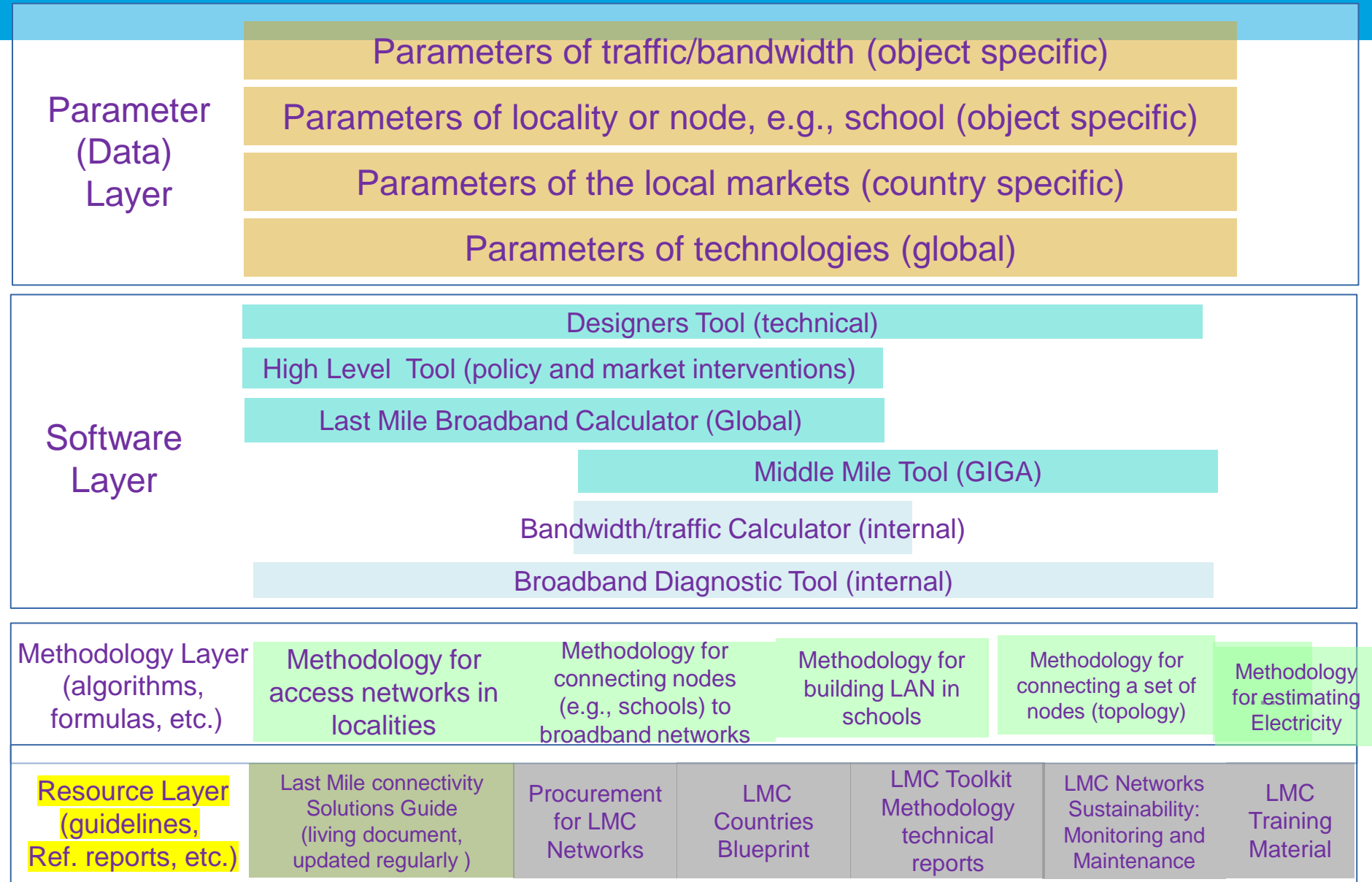
SUMMARY - Distance (km)		
AFR	AMS	ARB
326.063	385.852	189.516
Operators:93	Operators:63	Operators:41
ASP	CIS	EUR
812.666	385.852	444.818
Operators:85	Operators:36	Operators:79

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

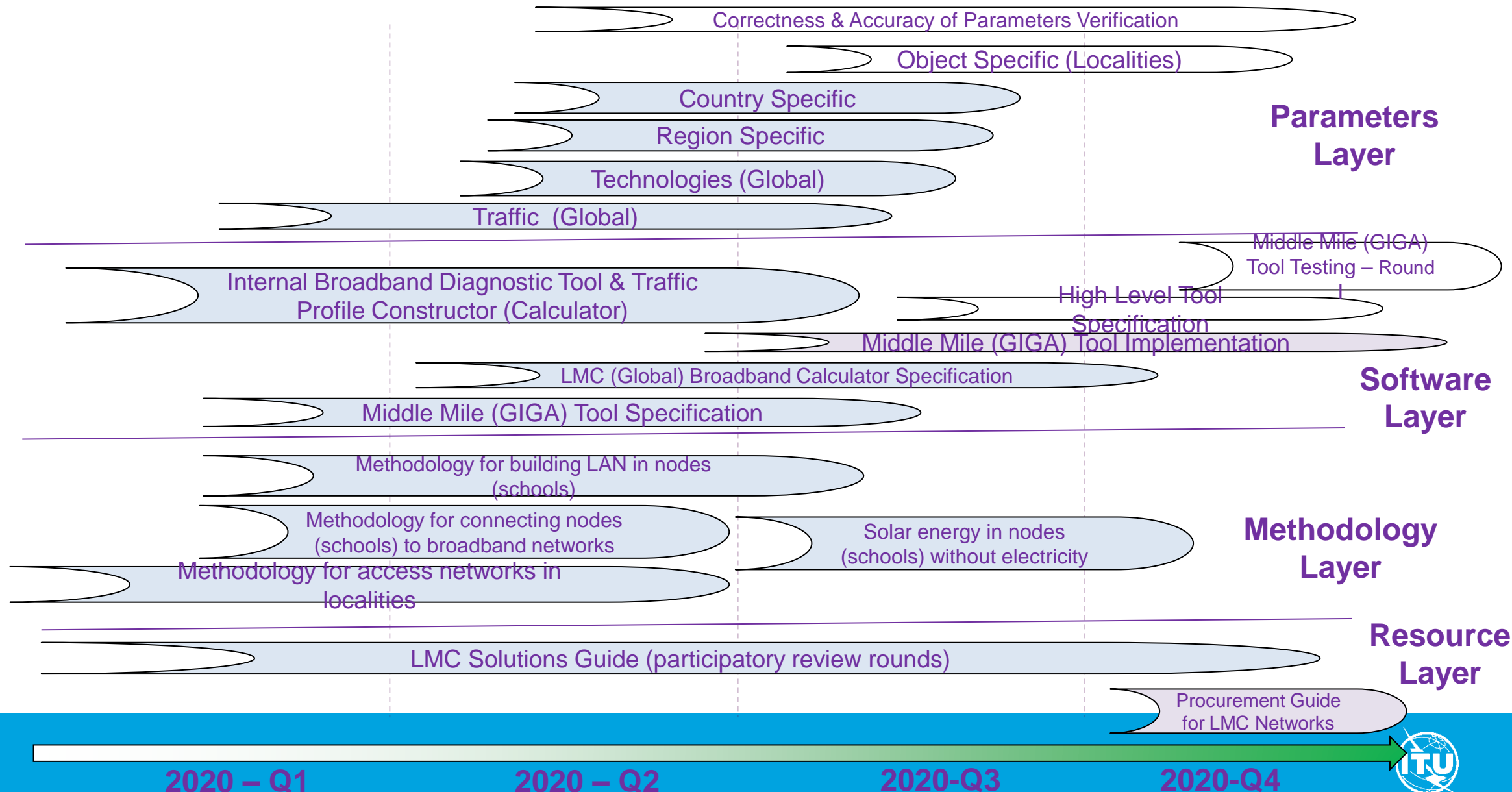
Introduction

- 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

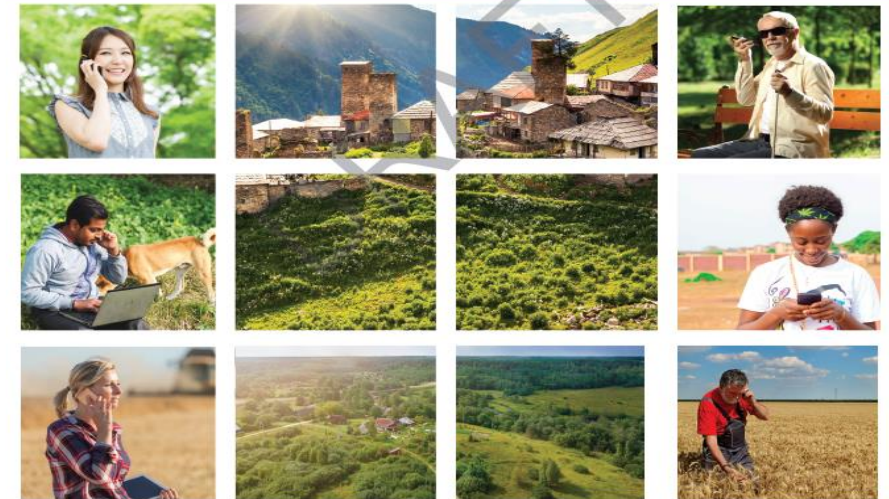


Resources

- Launched: December 2020
- <https://www.itu.int/en/ITU-D/Technology/Pages/LMC/LMC-Home.aspx>
- Procurement Guide
- Q1 2021

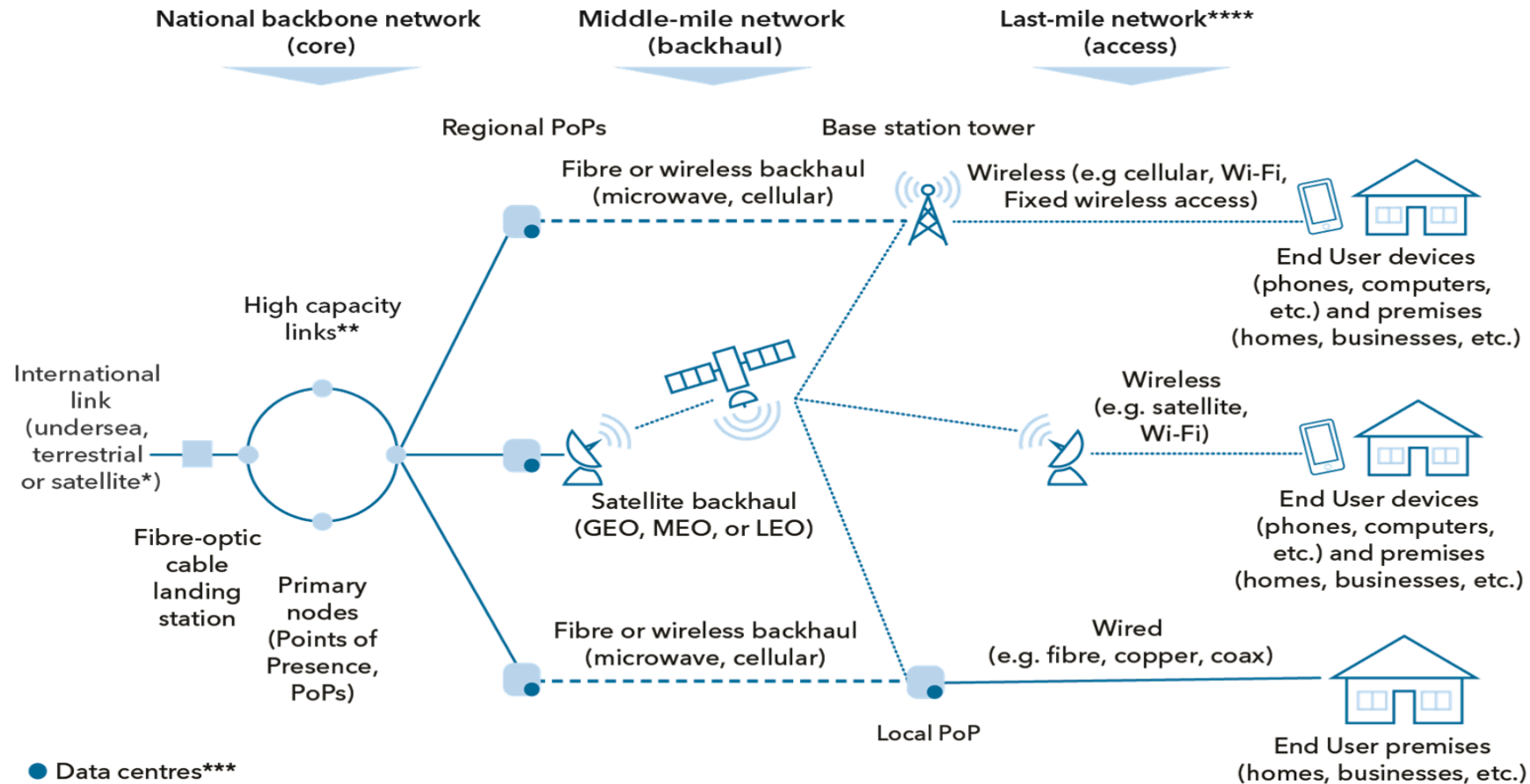
The Last-mile Internet Connectivity Solutions Guide

Sustainable connectivity options
for unconnected sites
2020



Introduction: Definitions – Describing a Telecommunications Network

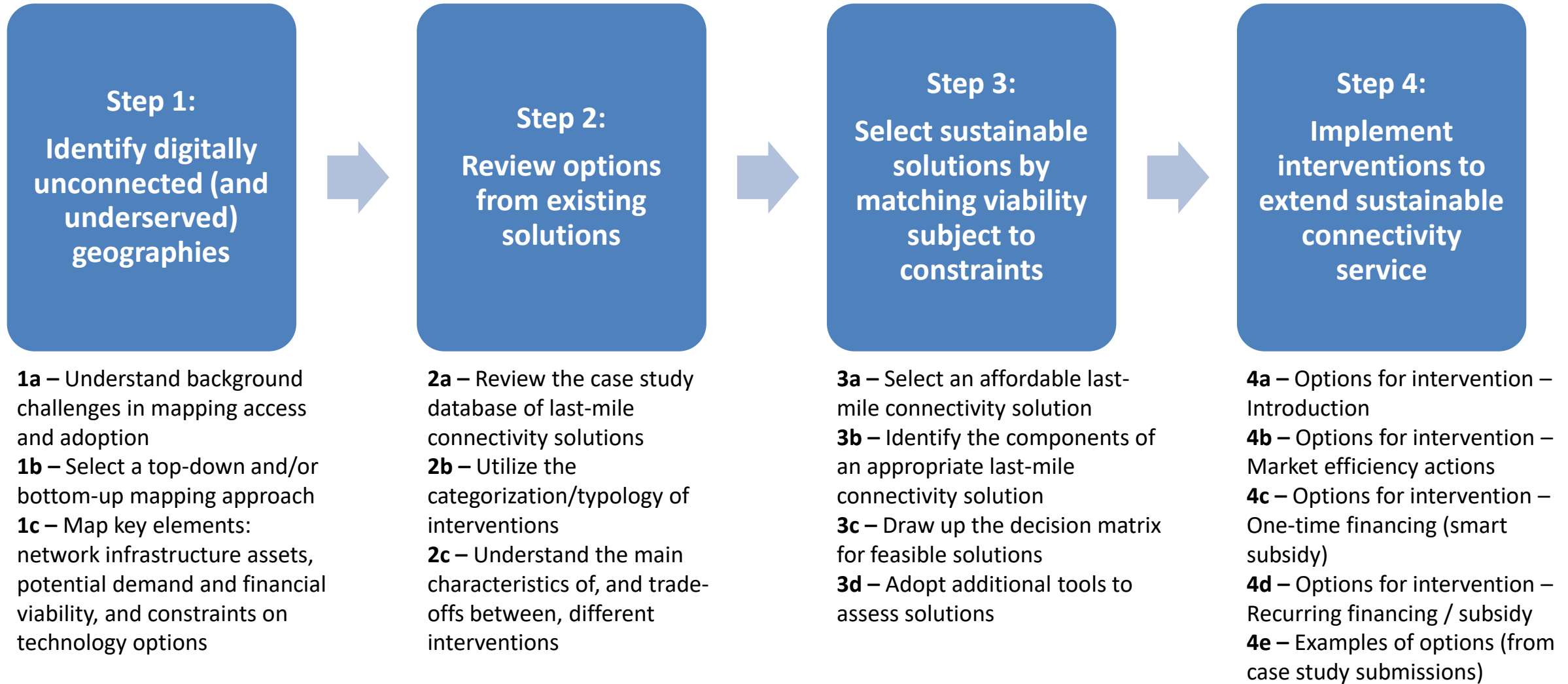
Figure 2: Telecommunications network components supporting last-mile interventions in developing countries



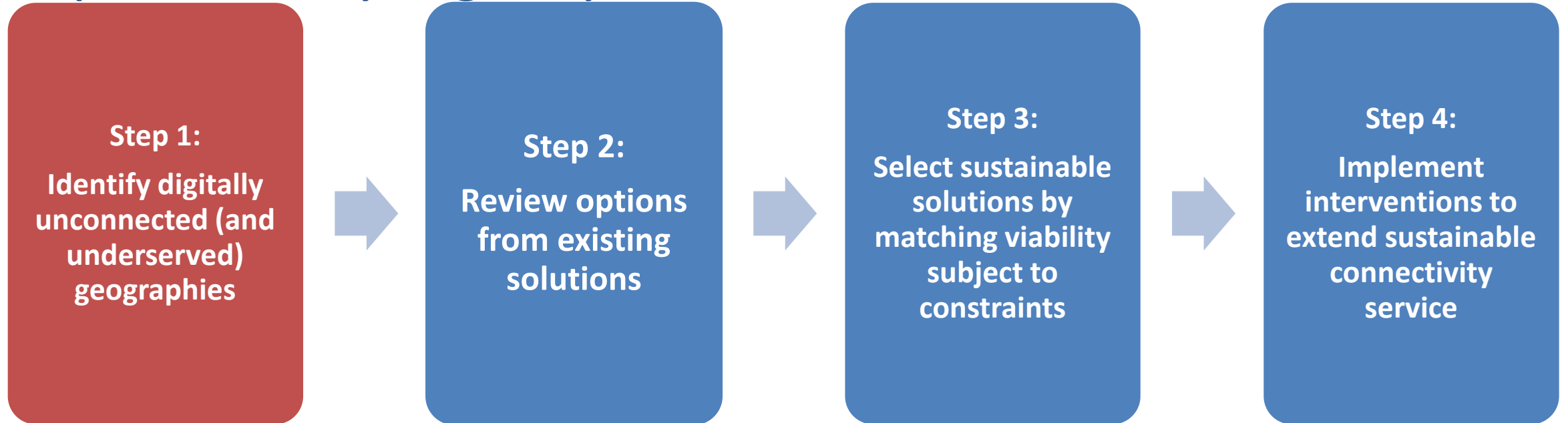
Source: Authors, adapted from various sources

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



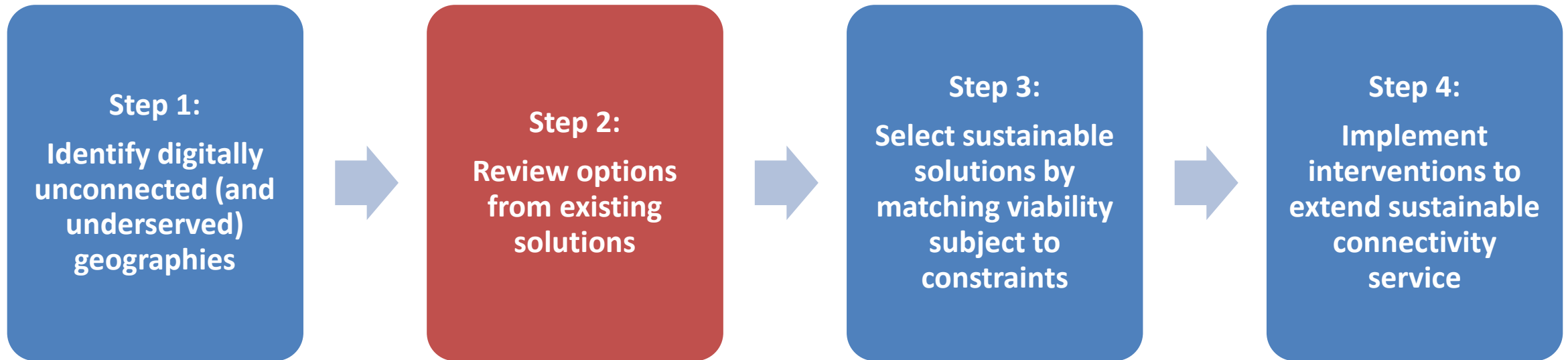
Step 1: Identify Digitally Unconnected Communities



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

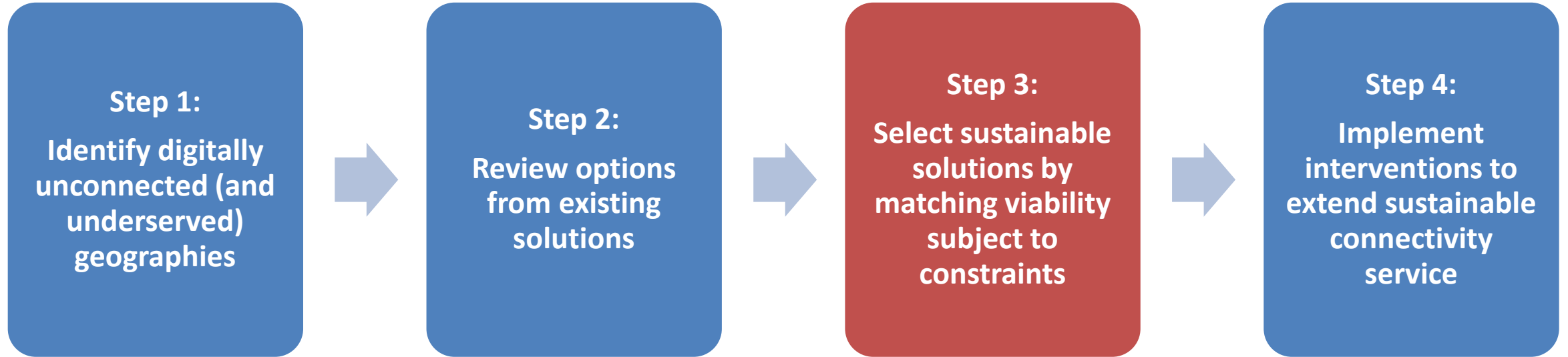
Step 2: Review options from the classification of existing solutions



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

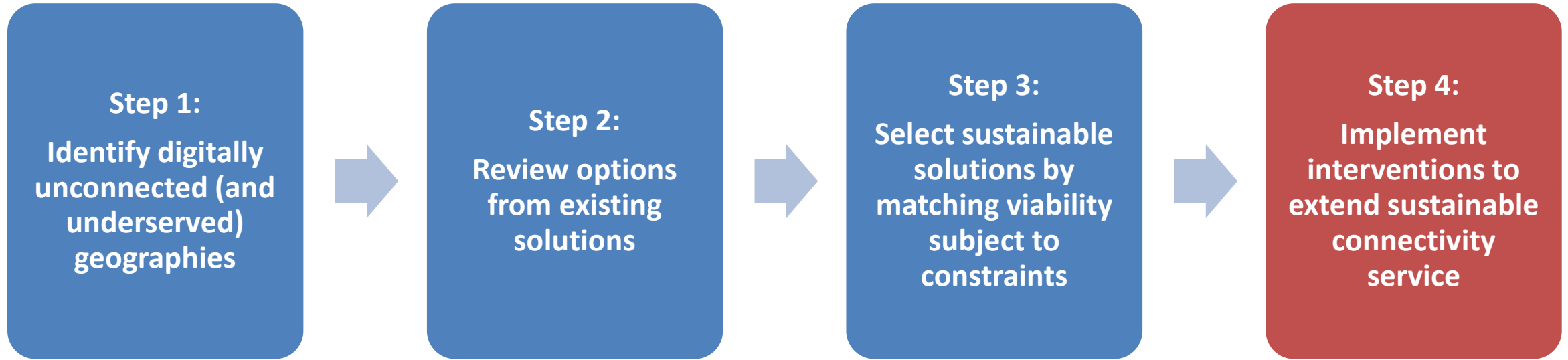
Step 3: Select Sustainable Solutions by Matching Viability Subject to Constraints



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

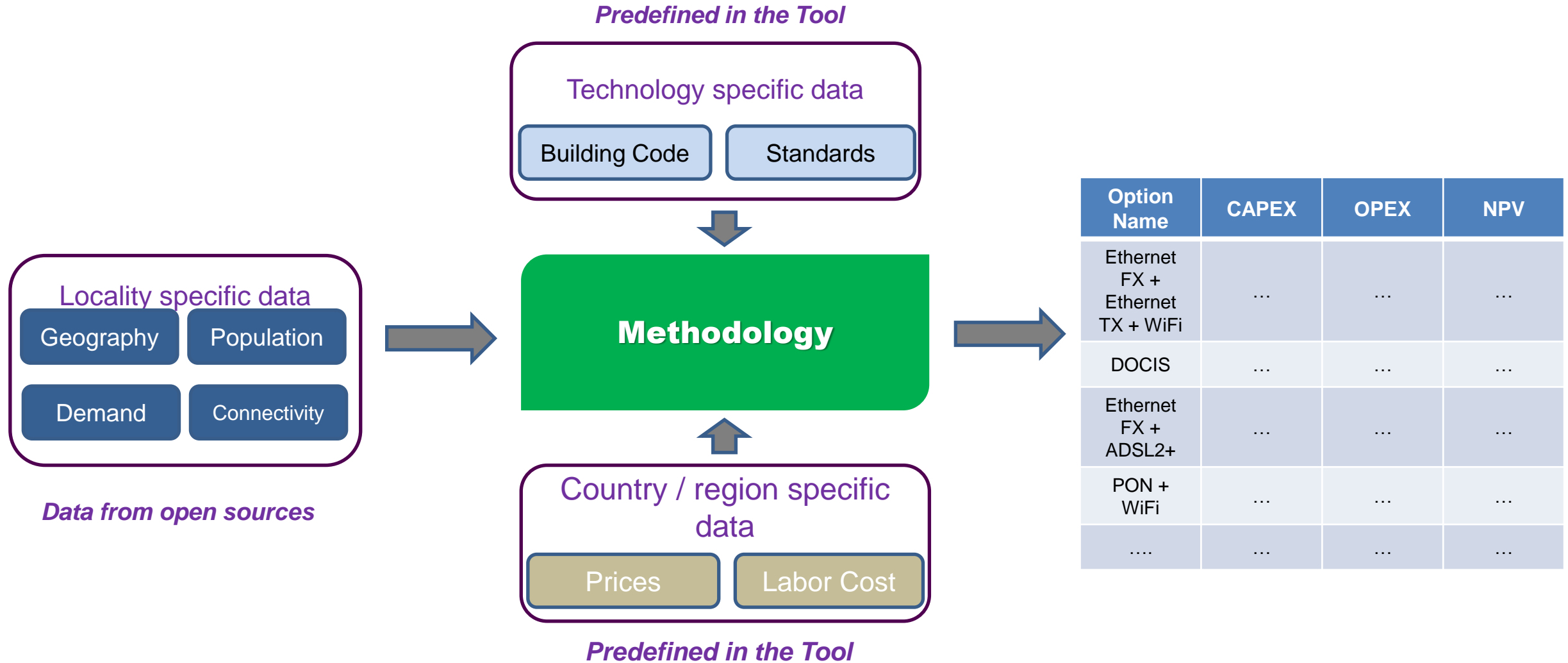


Step 4 activities to implement interventions to extend sustainable connectivity service:

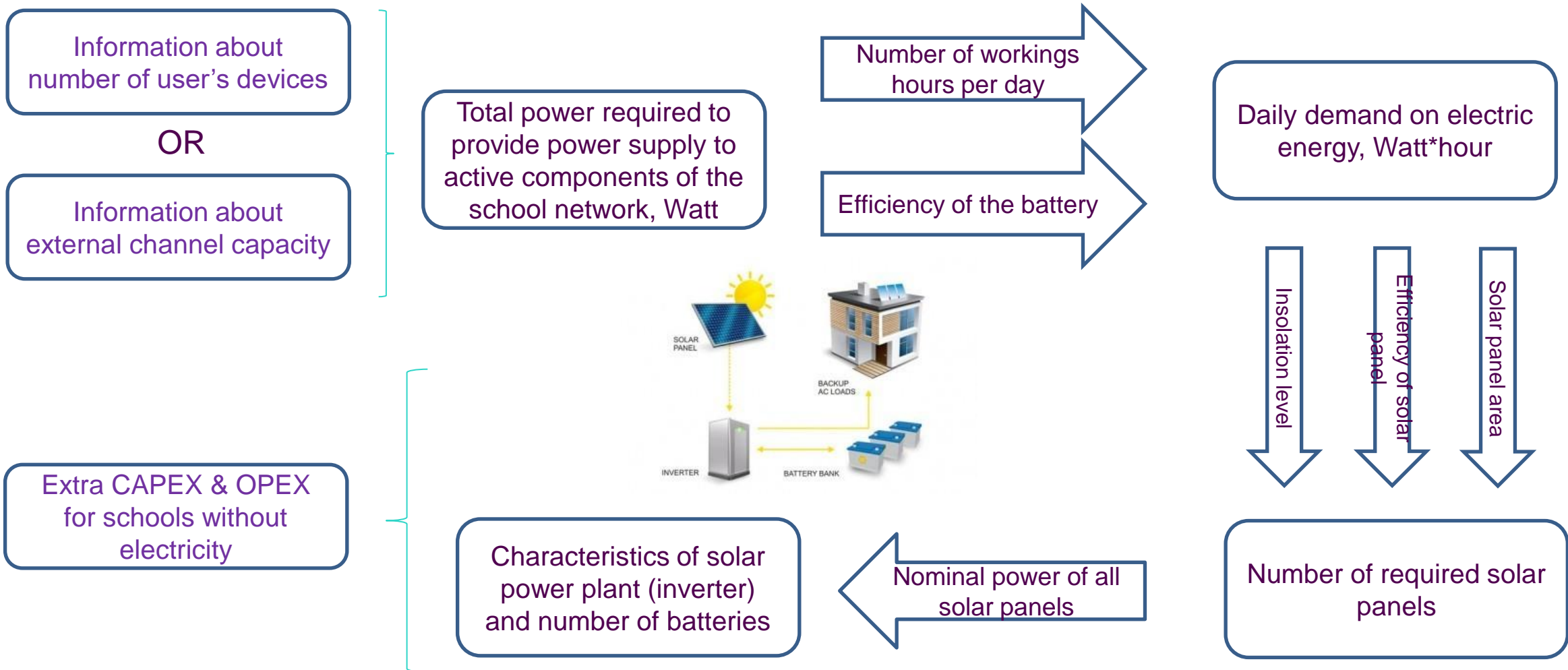
- 4a** – Options for intervention – Introduction
- 4b** – Options for intervention – Market efficiency actions
- 4c** – Options for intervention – One-time financing (smart subsidy)
- 4d** – Options for intervention – Recurring financing/subsidy
- 4e** – Examples of options (from case study submissions)

Methodology

Access networks (Last Mile) Methodology

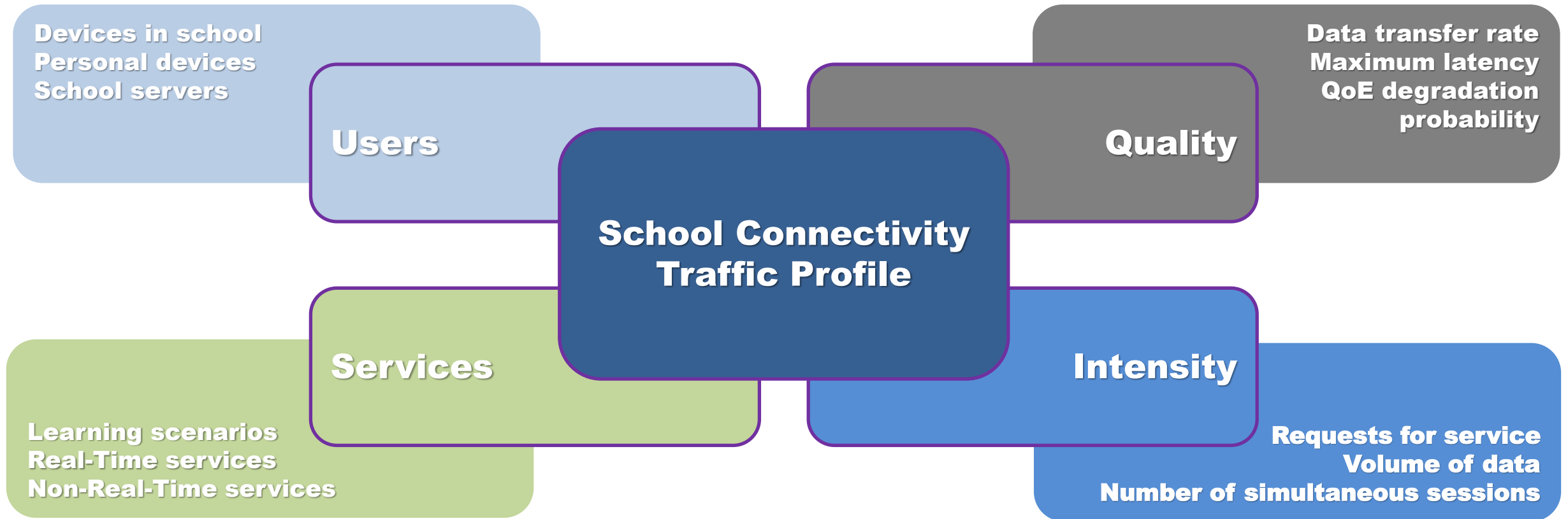


Electricity Methodology



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

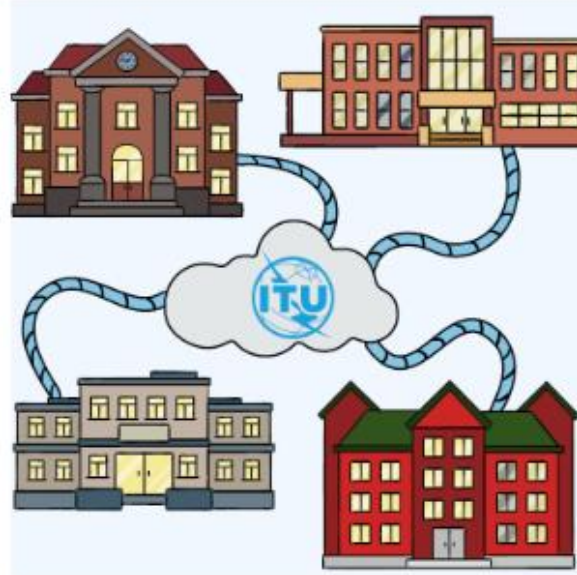
Middle Mile (GIGA) Tool: main screen

Home

About the project

Sign in

GIGA Broadband Calculation Tool



CONNECT MULTIPLE SCHOOLS

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 Identification (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	<u>Longitude</u>	<u>Latitude</u>	<u>Type of Cell Coverage</u> (2G / 3G / 4G)	<u>Availability of electricity</u> (Yes / No)	<u>Distance to the fiber*</u> , km	Required bandwidth*, Mbit/s	Middle-Mile	Topology
1	Adhibohol	Garissa	Hadado	1.698527813	39.21347046	3G	Yes	81.36	100		
2											
3											

</

Assumptions												
Workstations in primary school classrooms and laboratories	Mobile devices of primary school pupils	Workstations in secondary school classrooms and laboratories	Mobile devices of secondary school pupils	Workstations in high school classrooms and laboratories	Mobile devices of high school pupils	Workstations in teachers' offices	Mobile devices of teachers	Workstations in administrative personnel offices	Mobile devices of administrative personnel	Mobile devices of guests	The total number of computers (workstations)	The total number of mobile devices
Assumptions (you can change percentage based on the data in the list or directly put your values (tested several values))												
Average number of computers (workstations) in primary school classrooms and laboratories per 100 pupils, computers	Percentage of pupils who use mobile devices in primary school, %	Average number of computers (workstations) in secondary school classrooms and laboratories per 100 pupils, computers	Percentage of pupils who use mobile devices in secondary school, %	Average number of computers (workstations) in high school classrooms and laboratories per 100 pupils, computers	Percentage of pupils who use mobile devices in high school, %	Percentage of teachers who have personal workstations in the office, %	Percentage of teachers who use mobile devices, %	Percentage of administrative personnel who have personal workstations in the office, %	Percentage of administrative personnel who use mobile devices, %	Percentage of guests who use mobile devices, %		
15	30	15	40	20	60	20	80	40	90	100	74	512

- ✓ 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
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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							
#	School Name	Region	Subregion	Technology of Broadband Connection							
				Fiber Optic			Microwave Link			Satellite	
				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
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2	Kabochony	Eldoret	Baringo Central	42 08
---	-----------	---------	-----------------	-------


3	Kapkia	Eldoret	Baringo Central	48 59
---	--------	---------	-----------------	-------

4	Kapkomoi	Eldoret	Baringo Central	36 18
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Calculation Result									
Broadband (Middle-Mile) Connection									
Recommended technology		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
Based on maximum NPV (5-years)	Based on minimal cost of ownership (5-years)								
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 Constructor

General Requirements

Profile Name

Quality Level

Profile Type

Additional Information

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 personnel	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 characteristics	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

High Level Diagnostic & Recommendation Tool

STEP 4A. Apply Interventions ¹

Market Efficiency Interventions



Discount spectrum licences

Implement of "dig once" regulations

Blanket licensing for end-user terminal equipment

Secondary use of spectrum

Support of infrastructure sharing

Cancel and Go Back

High Level Diagnostic & Recommendation Tool

STEP 6. Modeling Results Visualization ¹



Now: 20
Before: 12

Geographic Coverage



Now: 59%
Before: 54%

Penetration rate



Now: 77M
Before: 100M

Required investments



Now: 1,2%
Before: 3,4%

Affordability



Now: 55M
Before: 55M

Cost of ownership



Now: 55M
Before: 34M

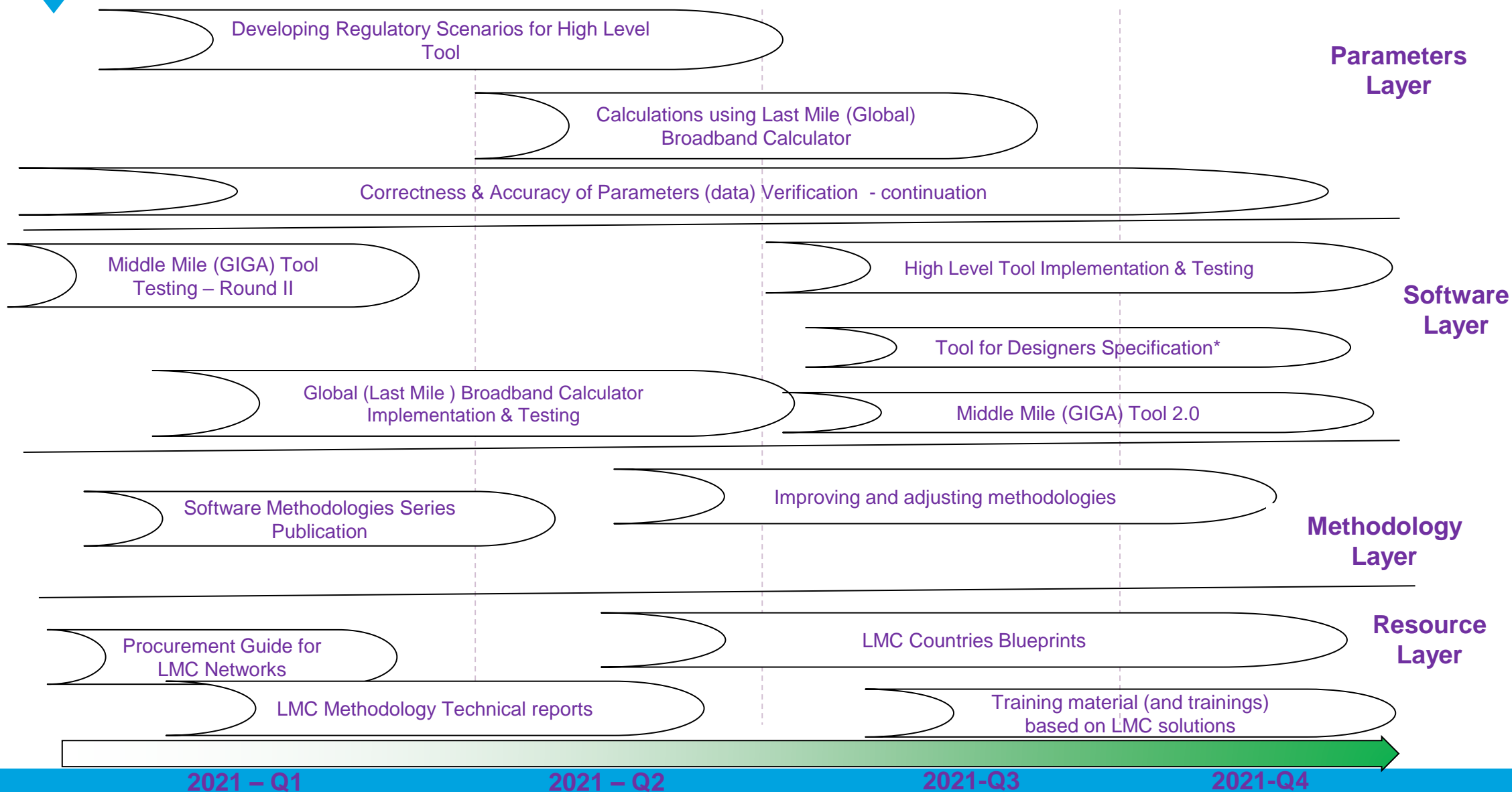
NPV

Cancel and Go Back

NEXT STEP >>

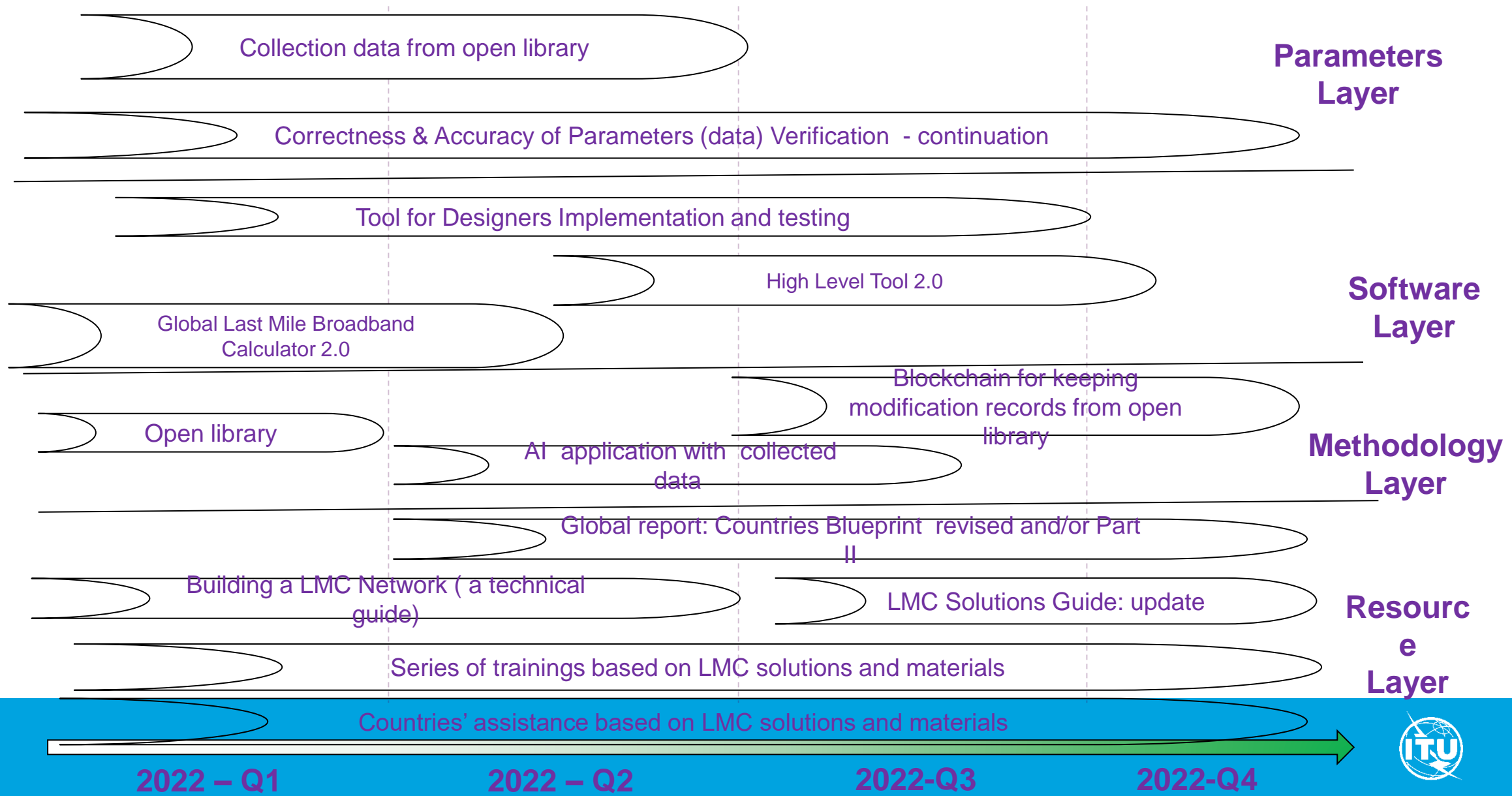
The main purpose of the tool – is to demonstrate (in gamified way with high level of visualization) to the High Level decision makers the key factors that could influent into the process of telecom networks deployment.

Last Mile Connectivity Toolkit Implementation Status - 2021



* The tool will be implemented in 2022

Last Mile Connectivity Toolkit Implementation Plan - 2022



Usage Scenarios

ITU

Integrated into Giga and Smart village/Smart islands.

Administrations and sector members

Can use on their own for national/business connectivity planning

Development partners

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



ituasiapacificregion [at] itu.int

Annex 2: Additional Resources for Mapping

Network Infrastructure Mapping

Fiber (Undersea & Terrestrial):

ITU – [Broadband Maps](https://itu.int/go/Maps): <https://itu.int/go/Maps>

Telegeography – [Submarine Cable Map](https://github.com/telegeography/www.submarinecablemap.com):

<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 station 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](#)

Introduction

Step 1:
Identify Communities

Step 2:
Review Options

Step 3:
Select Best-Fit Solutions

Step 4:
Implement
Interventions

Next Steps

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 \(Global Satellite Coalition\)](#)

Introduction

Step 1:
Identify Communities

Step 2:
Review Options

Step 3:
Select Best-Fit Solutions

Step 4:
Implement Interventions

Next Steps

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)

Introduction

Step 1:
Identify Communities

Step 2:
Review Options

Step 3:
Select Best-Fit Solutions

Step 4:
Implement
Interventions

Next Steps