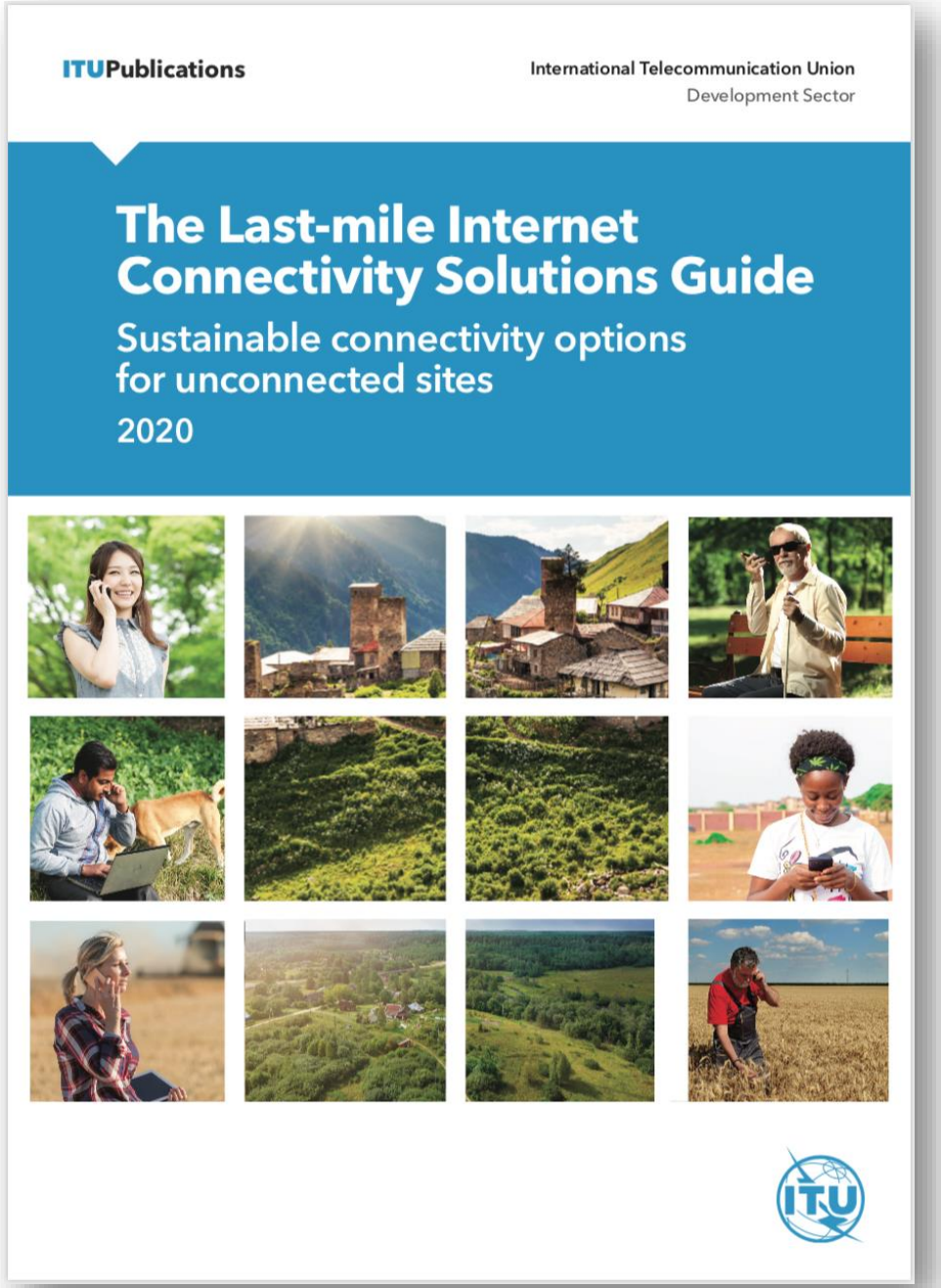


The Last-mile Internet Connectivity Solutions Guide:

Sustainable Connectivity Options for Unconnected Sites

Introduction: Background, Motivation and Objectives

The global focus on universal connectivity is driven in part by the fact that, despite the meteoric growth of Internet use and broadband connectivity, 49 per cent of the world's population, or 3.7 billion people, were still offline and excluded from the benefits of the global digital economy at the end 2019. Offline populations are particularly concentrated in least developed countries, where only 19 per cent of individuals were online in 2019. Regionally, less than half the populations of Africa and Asia-Pacific are online (29 and 45 per cent, respectively)

Figure 3: Individuals using the Internet, 2005-2019*

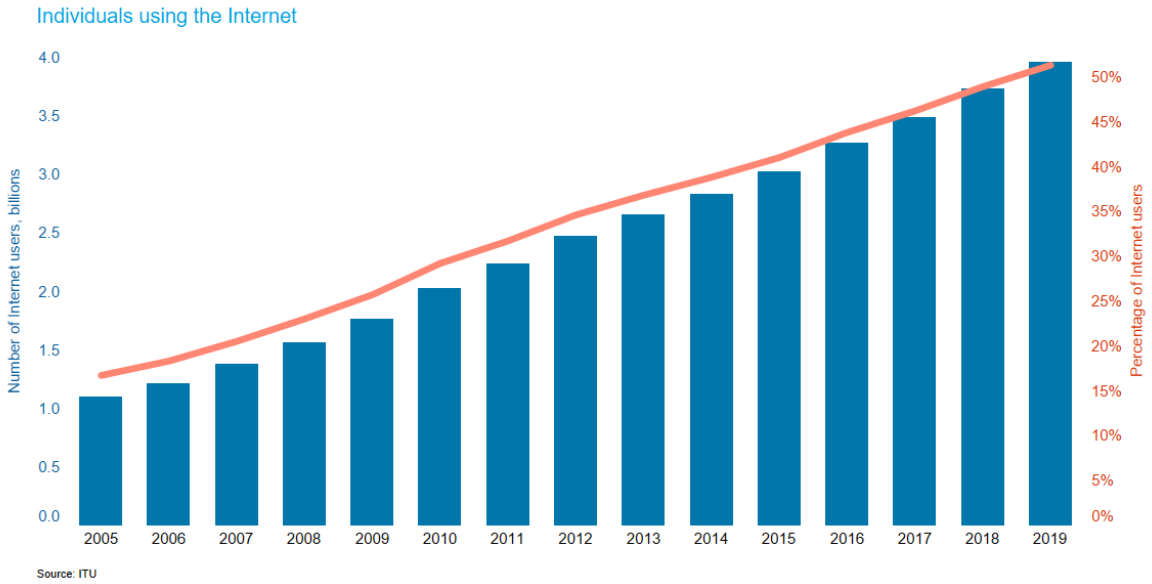
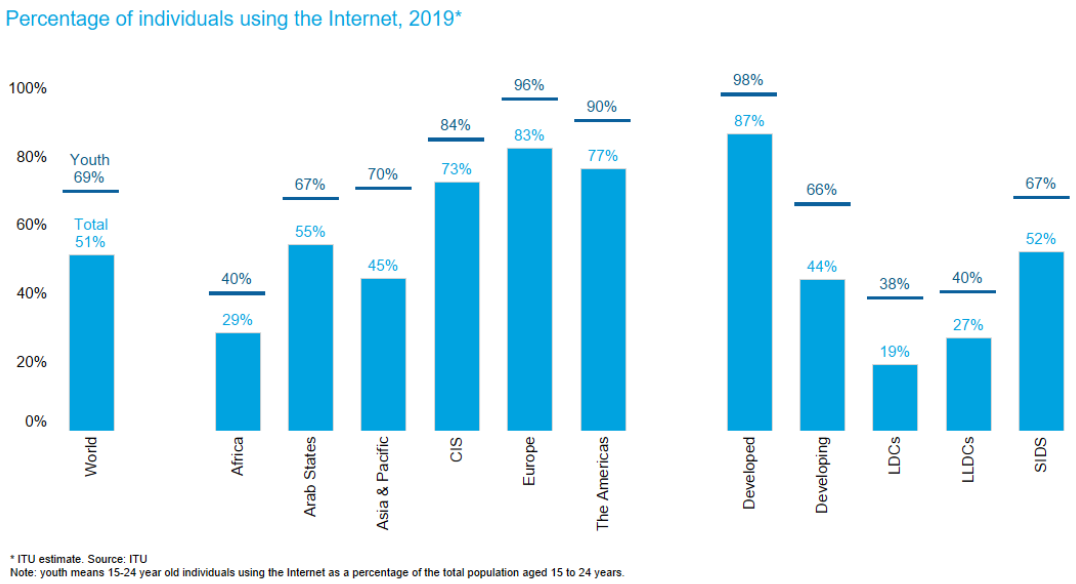


Figure 4: Percentage of individuals using the Internet, by region and development status, 2019



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

Introduction: 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

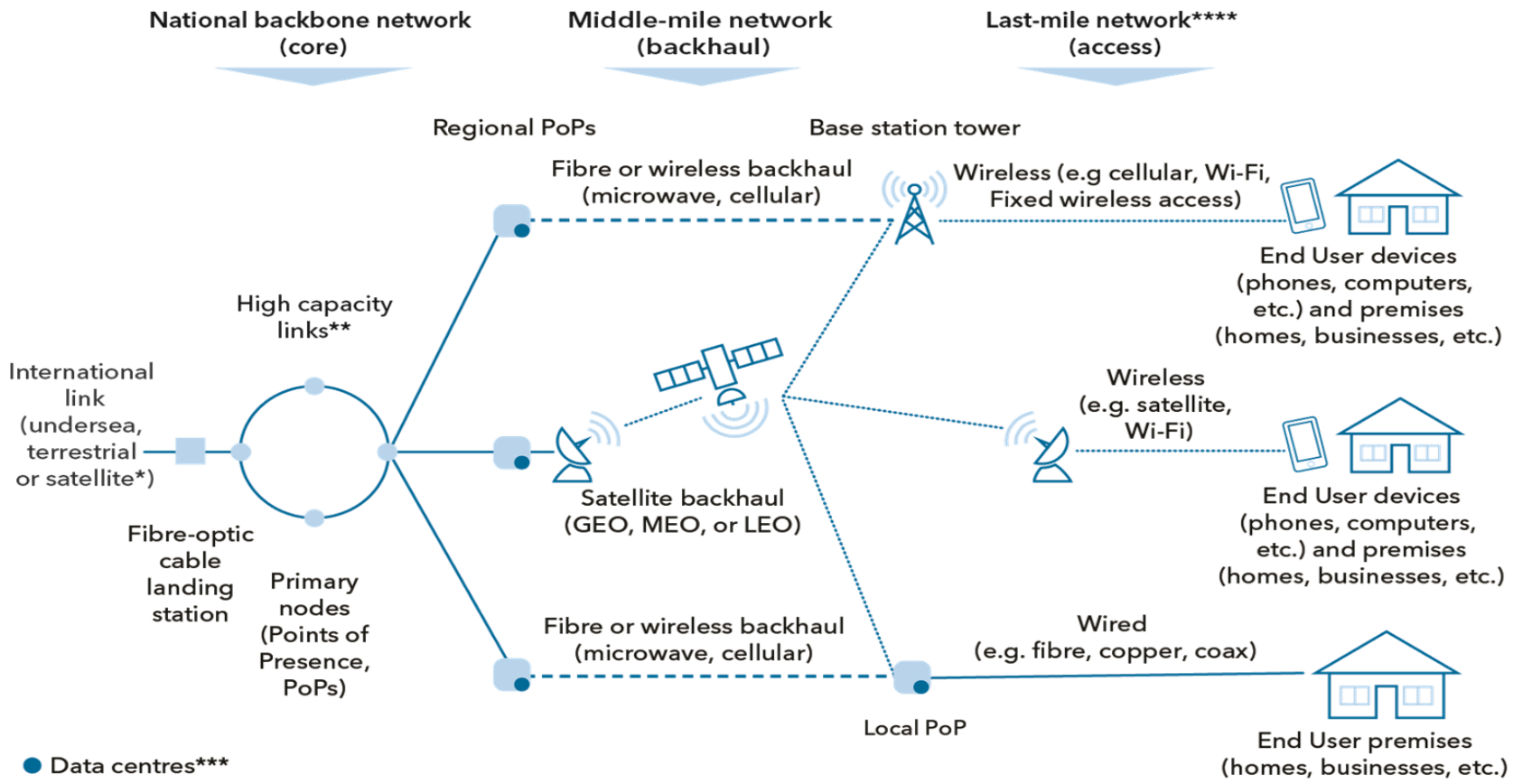
3a – Select an affordable last-mile connectivity solution
3b – Identify the components of an appropriate last-mile connectivity solution
3c – Draw up the decision matrix for feasible solutions
3d – Adopt additional tools to assess solutions

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)

Introduction: Definitions – Describing a Telecommunications Network

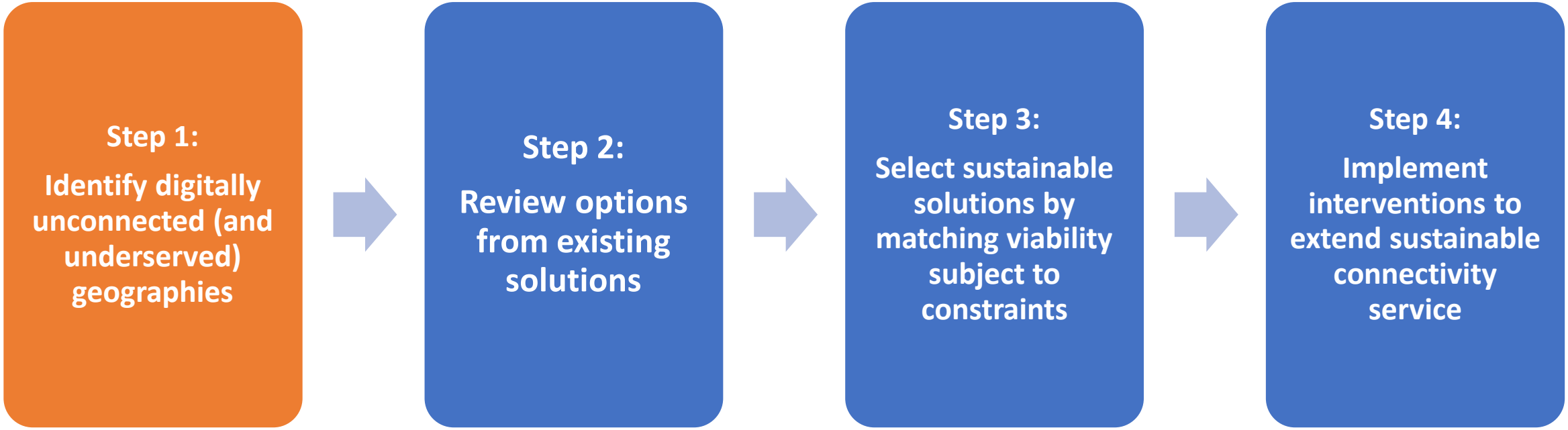
Figure 2: Telecommunications network components supporting last-mile interventions in developing countries



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.

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 1b: Select a Top-Down and/or Bottoms-Up mapping approach

There are two main approaches to begin geographically mapping network infrastructure and access, depending on the geographic scope of the exercise.

The first is **top-down** and involves mapping a large geographic area by accessing secondary data sources and identifying gaps in infrastructure service. This differs from the more granular and localized **bottom-up** approach, which starts with an ex-ante selection of a specific locality and builds an understanding of current conditions through a direct census of residences and physical survey of network assets. Both approaches overlay infrastructure assets and coverage against population density. The figure below differentiates between the two, but a given mapping exercise may take elements from both approaches, accessing secondary mapping of network assets, population density and other relevant infrastructure, and combining it with an on-the-ground survey and census.

Figure 13: Differentiating between two different approaches to mapping unconnected and underserved populations

Top-down approach:

Large geographic areas (national or sub-national) are mapped by accessing secondary mapping data in order to identify infrastructure coverage gaps.
Additional characteristics:

- Data gathered from secondary sources such as national government agencies or third-party aggregators (e.g. satellite data, operator infrastructure, etc.)
- Tends to cover large geographic areas
- May develop a multipronged approach to connectivity interventions beyond a single site/location

Bottom-up approach:

Starts with the specific, targeted locality, mapping local data and testing for different aspects of network infrastructure availability.
Additional characteristics:

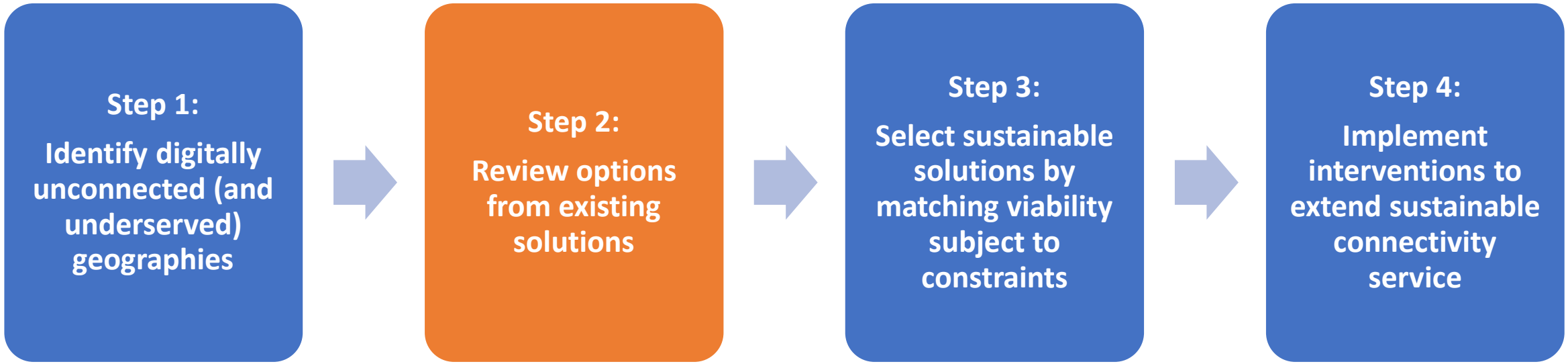
- Local mapping (testing network infrastructure available in the vicinity)
- Adding socio-demographic attributes at the local level collected via census
- Includes relevant geographic and environmental conditions

Step 1b: Top-Down Infrastructure Mapping Examples

Table 5: Top-down infrastructure mapping: examples

Map name	Geographic coverage	Network type	Publicly available or commercial service	Data downloadable to the public	URL
ITU Broadband Maps	Global	Terrestrial fibre, microwave and undersea fibre	Public	Limited access	https://itu.int/go/Maps
Telegeography Submarine Cable Map	Global	Undersea fibre	Public	Yes	https://www.submarinecablemap.com/ and https://github.com/telegeography/www.submarinecablemap.com
African Terrestrial Fibre Optic Cable Mapping Project (AfTerFibre)	Africa	Terrestrial fibre and undersea fibre	Public	Yes	https://afterfibre.nsrc.org/
The Connected Pacific	East Asia and the Pacific	Undersea fibre	Public	Yes	https://connectedpacific.org
Satbeams	Global	Satellite	Public	Some	https://www.satbeams.com/
GSMA Mobile Coverage Maps	Africa (8 countries)	Terrestrial cellular	Public	No	http://www.mobilecoveragemaps.com/
Masae Analytics	Global	Terrestrial networks and undersea	Commercial	No	https://www.masae-analytics.com/
InfraNav	Global	Terrestrial networks and undersea	Commercial	No	https://www.infranav.com/
Fraym	Africa	Terrestrial networks and undersea	Commercial	No	https://fraym.io/
Towersource (infrastructure)	Global	Terrestrial networks	Commercial	No	https://www.towersource.com/
mapELEMENTS (coverage)	Global	Terrestrial mobile coverage	Commercial	No	https://www.mapelements.com/
OpenSignal	Global	Terrestrial cellular coverage	Commercial	No	https://www.opensignal.com/

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

Review Step 2a: The Last-Mile Connectivity Case Studies Database

In order to inform the process of identifying appropriate affordable solutions, this analysis started by developing the Last-Mile Connectivity Case Studies Database, a wide-ranging database of different case studies of last-mile connectivity solutions. The solutions were sourced from primary (direct engagement with solution managers and implementers) and secondary sources (reports, etc.). The cases were classified in 17 dimensions across five main categories (reference material, entity, technologies, locality characteristics, additional information).

As of August 2020, the database contained 123 cases, of which 51 are from primary sources and 72 from secondary sources, particularly 1 World Connected and APC / IDRC GIS Watch 2018. The database is a live document and will be continually updated as more case studies are submitted.

Table 10: Category of characteristics of the interventions in the LMC Case Studies Database

Reference Material	Entity	Technologies	Locality characteristics	Additional information
Organization or project name; country	Access network operational entity; revenue model; degree of subsidy	Backhaul technologies; access network technologies; primary device for access	Population density/ urbanization level; population size; geographic area; topography; per capita income/ARPU of users; literacy levels; other socio-demographic and environmental factors	Still in operation; regulatory and policy considerations

Review Step 2b: Categorization / typology of interventions

The review of 123 different interventions presented in the Last-Mile Connectivity Case Studies Database showed that interventions differed along two axes:

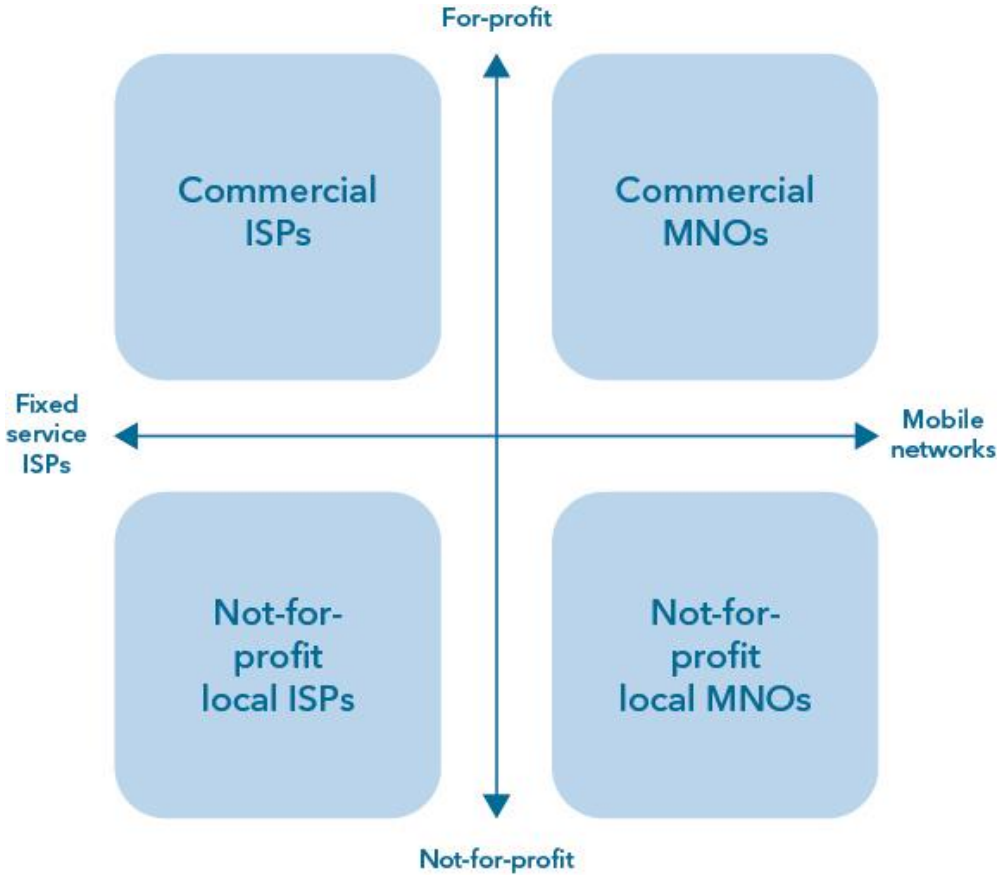
The first is the **type of network service**, as defined by the primary access network technology utilized. Interventions focused either on:

a. M**obile network deployments** providing various mobile wireless services, including voice service, and where the end-user device is mobile and non-stationary; or,
b. General **internet service providers (ISPs)** that utilized a range of different technologies, both fixed and wireless, to provide data-focused services.

The second axis relates to **profit**. While most entities incorporated formal business operations in partnership with commercial services, some interventions were either:

a. **not-for-profit**, delivering connectivity service without an emphasis on commercial returns; or
b. **commercial**, basing investment decisions on economic return calculations.

Figure 19: Categorizing last-mile interventions based type of network and profit considerations



Review Step 2b: Categorization / typology of interventions

Analysis and review of the range of last-mile connectivity interventions collected in the database suggests that the solutions can be effectively organized by type of profit motive (commercial versus not-for-profit) and access network technology (mobile cellular network operators versus generalized Internet (data) service providers). The categorization is shown below.

Table 11: Categorizing last-mile Internet connectivity interventions

		Access network technology	
		Mobile networks	***Fixed-service ISP***
Revenue model	**Commercial**	**Commercial MNOs:** Traditional MNO service provision, and similar interventions where the user and device are mobile	**Commercial ISPs:** ISPs, wireless ISPs, focusing on rural and urban communities with both fixed-line and wireless technologies
	Not-for-profit	**Not-for-profit local mobile networks:** Communities owning and/or operating their own cellular network infrastructure, sometimes in partnership with traditional MNOs	**Not-for-profit local ISP networks:** Networks established by non-profits, governments or communities, focused on providing access to underserved areas

Review Step 2c: Characteristics & Trade-offs – Common Access Network Technologies (Wireless)

Table 17: Comparison of common wireless access network technologies

Access network technology	Potential throughput / QoS	Range	Capital expenditure to deploy new network	Operating expenses	Infrastructure required	Suitability for rural deployments	Spectrum licensing requirement	Access device type
Wi-Fi: 802.11	2 Mbit/s (a) to 10 Gbit/s (ax)	100s of m	Low	Low	Wi-Fi routers	Yes, but backhaul required (satellite, microwave or fibre)	No specific licence but compliance with technical specifications via "blanket licence" under non-interference/non- protection regime	Wi-Fi enabled smartphones, tablets, computers
Mobile cellular (2G, 3G, 4G, 5G)	0.1 – 1000 Mbit/s	5 to 15 km	Medium to high	Medium to high	Towers and radio equipment	Yes, but backhaul required (satellite, microwave or fibre)	Yes	Cellular mobile phones, laptops, personal computers (via dongles)
Fixed wireless access (4G/ 5G)	20 – 1 000 Mbit/s	Up to 10 km	Low to medium	Low	Towers and radio equipment	Maybe, depending on financial viability and demand	Depends on country regulations	Consumer premises modems to Ethernet or Wi-Fi
Satellite (HTS GEO and MEO)	5 – 150 Mbit/s	1 000s of km	High (for new satellite deployment); low (for end-user terminals)	Low	Earth station, satellite, very-small-aperture terminal	Yes	Yes	Very-small-aperture terminal, consumer premises modems to Ethernet or Wi-Fi

Note with the evolution of 4G and 5G, throughput can reach up to 1 Gbps

Sources: adapted from various sources, including the European Union, Cisco, Huawei, ITU, the Inter-American Development Bank, the World Bank and the EMEA Satellite Operators Association

Review Step 2c: Characteristics & Trade-offs – Common Access Network Technologies (Wireline)

Table 19: Comparison of common wired access network technologies

Access network technology	Potential throughput / QoS	Range	Capital expenditure to deploy new network	Operating expenses	Infrastructure required	Suitability for rural deployments	Additional regulatory issues	Access device type
Fibre	100 – 1 000 Mbit/s	100s of km	Overhead cabling: low to medium	Medium	Tower, poles, cabinets, active network equipment	In some cases, with sufficient purchasing power and population densities	Pole attachment	Fibre modem to Ethernet-enabled devices or to Wi-Fi
			Below ground: medium to high (new excavation)	Low to medium	Subterranean duct work, cabinets, active network equipment	No	Right of way	
Coax (cable)	Up to 200 Mbit/s	Up to 100 km	Low to medium	Low to medium	Tower, poles, cabinets, active network equipment	In some cases, with sufficient purchasing power and population densities	Pole attachment	Cable modem to Ethernet-enabled devices or to Wi-Fi
Copper	0 to 24 Mbit/s (for ADSL, ADSL 2, ADSL 2+); 100 Mbit/s (for VDSL, VDSL2, Vectoring); 1 Gbit/s (G.Fast)	0.1 to 5 km	Low to medium	Low to medium	Tower, poles, cabinets, active network equipment	In some cases, with sufficient purchasing power and population densities	Pole attachment	Modem to Ethernet-enabled devices or to Wi-Fi

Sources: adapted from various sources, including the European Union, Cisco, Huawei, ITU, the Inter-American Development Bank, the World Bank and the European School of Antennas

Review Step 2c: Characteristics & Trade-offs – Backhaul (cont.)

Table 24: Comparison of backhaul technologies

Backhaul technology	Potential throughput/QoS	Range	Capital expenditure to deploy new network	Operating cost	Infrastructure required	Suitability for rural deployments	Advantages	Disadvantages
Microwave	5 – 200+ Mbit/s	100s of km	Lower	Lower	Radio equipment, towers/poles	Yes	High capacity; low-cost equipment; low-cost deployment	Requires line of sight; licensing constraints
Satellite backhaul (GEO, MEO)	1 – 1 600 Mbit/s	1 000s of km	Medium to high	Medium to high	Satellites, hub earth stations, remote earth stations	Yes	Wide coverage; ease of deployment; overcomes topographical challenges	Latency; cost
Fiber	100 – 1000 Mbit/s	100s of km	High	Medium	Fibre-optic cable installed in-ground or overhead via poles	Maybe	Highest speeds; reliability; flexibility (upgrades)	Cost; deployment time; limited geographic reach

Source: adapted from various sources, including the European Union, Cisco, Huawei, ITU, the Inter-American Development Bank, the World Bank and the EMEA Satellite Operators Association (technical references listed in Annex 2)

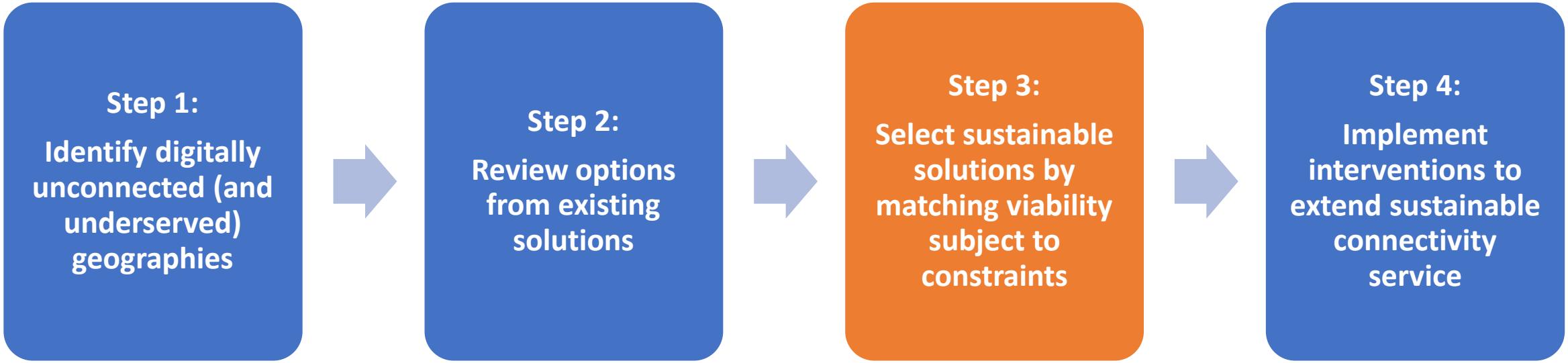
Review Step 2c: Characteristics & Trade-offs – Emerging Technologies

Table 25: Comparison of emerging technologies in connectivity

Technology	Wired or wireless	Potential throughput / QoS	Range	Infrastructure required	Suitability for rural deployments	Spectrum licensing requirement	Backhaul suitability	Access device type
HAPS	Wireless	Up to 30 Mbit/s	1 000s of km	High altitude balloons, autonomous drones	Yes	Yes	Could work for both backhaul and access	Cellular devices in last-mile cases (such as Google Loon)
LEO satellite		Up to 100 Mbit/s	1 000s of km	LEO satellites (for new network deployments)	Yes	Yes	Could work for both backhaul and access	To be determined
Millimeter wave		Up to 20 Gbit/s	1 to 10 km	Towers and radio equipment, fibre backhaul	No	Yes for certain bands, some unlicensed / licence-exempt	Local backhaul	To be determined
Free-space optical communication		10s to 100s of Gbit/s	1 to 10 km	Specialized equipment using light to transmit high-speed data	Yes, but requires line-of-sight data transmission	No	Local backhaul	Used for backhaul
TV White Space		5 – 150 Mbit/s	10 to 25 km	Towers and radio equipment	Yes, especially for non-line of sight	Authorization of use required under the opportunistic use principle	Could work for both backhaul and access	Consumer premises modem to Ethernet or Wi-Fi
LoRa		Up to 50 Kbit/s	10s of km	Towers and radio equipment	Yes (though very low throughput)	No (utilizes licence-free industrial, scientific and medical bands)		Long-range radios to IoT devices / applications
Power line communications: fibre via overhead medium-voltage distribution lines	Wired	100 – 1 000 Mbit/s	100s of km	Tower, poles, cabinets, active network equipment	Yes (eight times longer than high voltage lines)	No	Yes	Fibre modem to Ethernet-enabled devices or to Wi-Fi

Source: adapted from various sources, including the European Union, Cisco, Huawei, ITU, the Inter-American Development Bank, the World Bank and the EMEA Satellite Operators Association (technical references listed in Annex 2) . * Other emerging communication technologies are in use or entering the market. However, many of these (radio-frequency identification, Bluetooth Low Energy, near field communication, Light Fidelity, Zigbee, etc.) are not suitable for rural deployments. Wimax deployments appear to have peaked globally and are on the decline. Whereas TV White Space is still at a nascent stage of ecosystem growth and deployment.

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



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

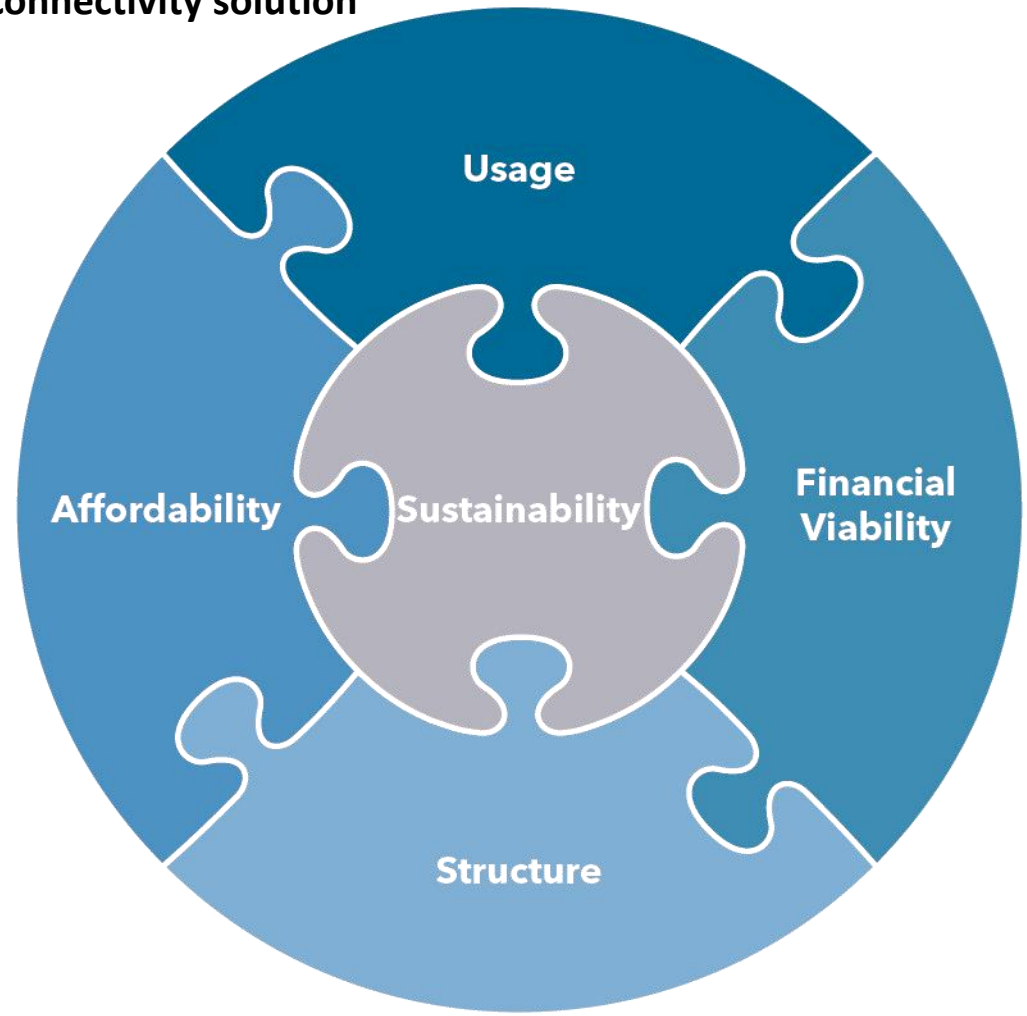
3a – Select an affordable last-mile connectivity solution
3b – Identify the components of an appropriate last-mile connectivity solution
3c – Draw up the decision matrix for feasible solutions
3d – Consider additional tools to assess solutions

Selection Step 3a: Selecting an Affordable Last-Mile Connectivity Solution

To identify suitable last-mile connectivity interventions, after a specific unconnected geography / locality has been selected, it is necessary to first determine the five main aspects of a given situation that serve as binding constraints and can provide direction for any possible solution.

1) **Affordability** – Ensuring that connectivity service user pricing falls within a given affordability threshold, such as the 2 per cent of monthly GNI per capita for 1GB of mobile broadband data discussed above.
2) **Usage** – Identifying the applications and services that need to be available to the locality, and the level of QoS that those applications and services require.
3) **Financial viability** – This includes measuring the economic viability for private investment of the connectivity service, based on estimates of ARPU, availability of backhaul / middle-mile connectivity, options for different local access technologies and the potential level of the service's QoS.
4) **Structure** – This involves articulating the service delivery business model and identifying any regulatory constraints on the model and technologies utilized.
5) **Sustainability** – This requires an understanding of the service's revenue model and of any potential subsidy (one-time and/or recurring).

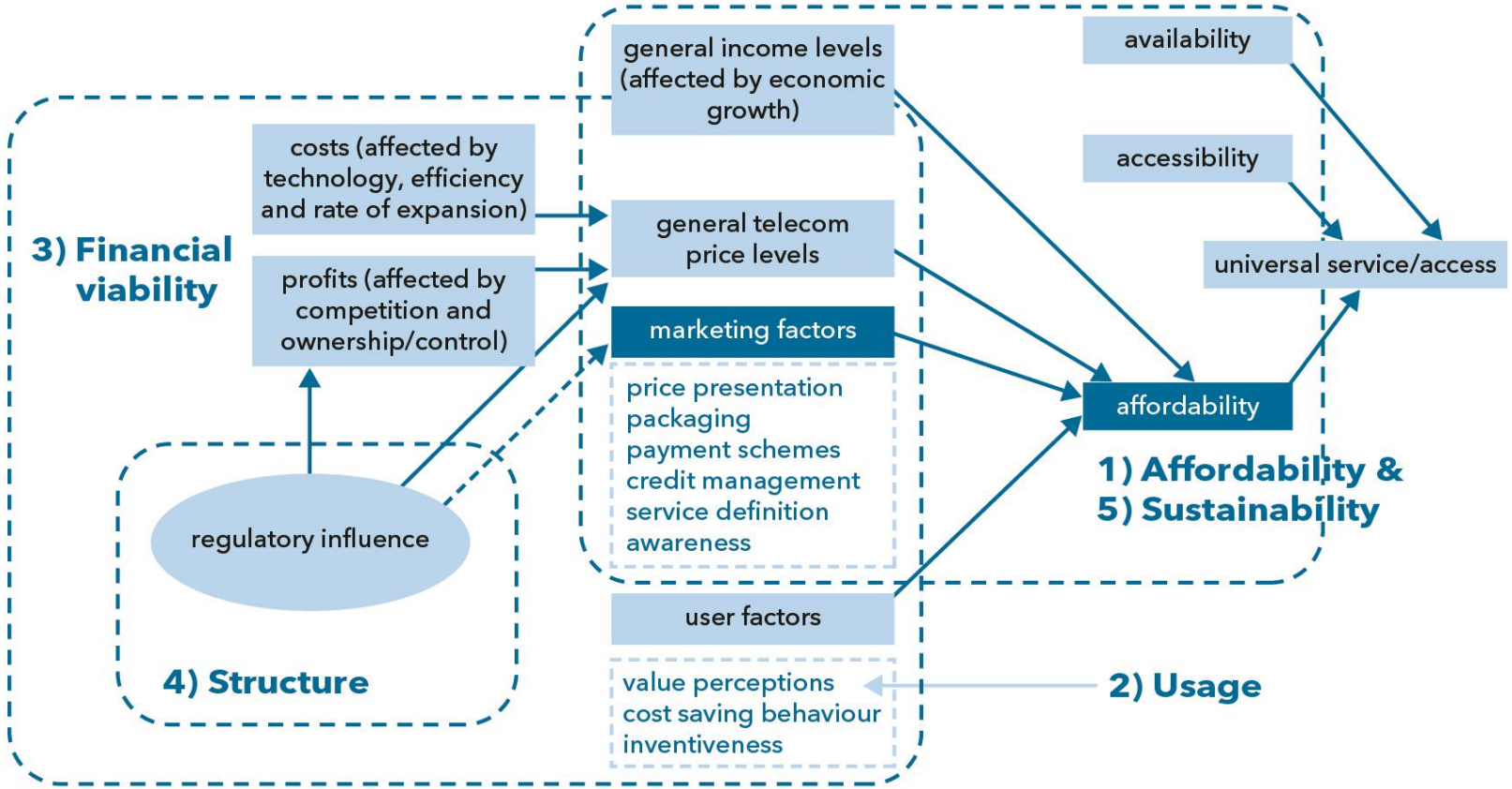
Figure 32: Components in selecting a sustainable last-mile connectivity solution



Selection Step 3a: Selecting an Affordable Last-Mile Connectivity Solution

The five factors in selecting an affordable last-mile connectivity solution map to other frameworks of universal access components in the figure below. Regulatory influence is the starting point for economic viability, mirroring the layered intervention approach beginning with market-expanding interventions that increase market efficiency. However, a government may want to provide universal access even when the profitability threshold is not achieved, such as with policy and regulatory interventions such as subsidies, tax alleviations, and free or low-cost licensing.

Figure 33: The components of a sustainable last-mile connectivity solution related to other frameworks



Source: adapted from C. Milne, Improving Affordability of Telecommunications: Cross-Fertilization between the Developed and the Developing World (15 August 2006), TPRC 2006. Available at SSRN: https://ssrn.com/abstract=2104397

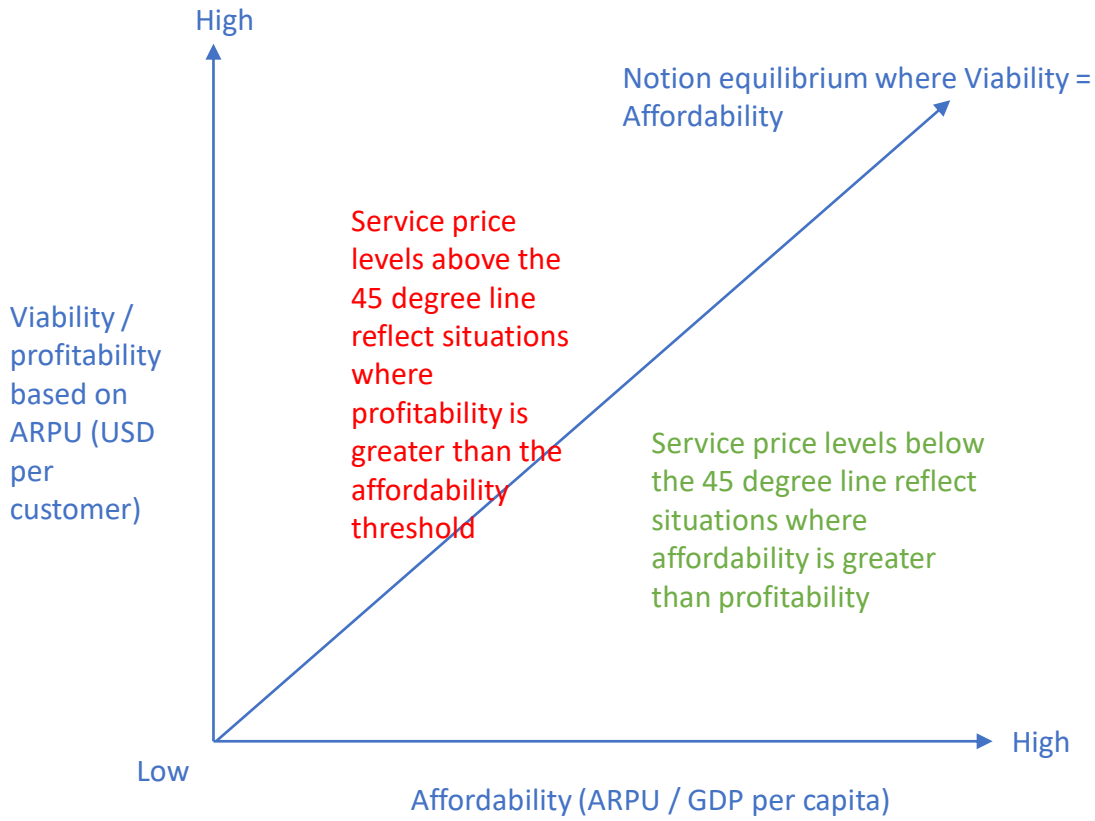
Selection Step 3a: Selecting an Affordable Last-Mile Connectivity Solution

Financial viability versus affordability: It is worth stressing that the financial viability of establishing service (considered from the point of view of the investor, whether the project is a commercial investment or a subsidized deployment) is different from the affordability of the service provided (considered from the point of view of individuals in the prospective underserved locality).

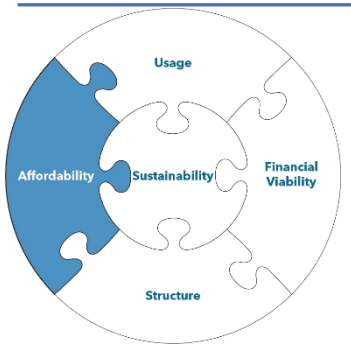
While financial viability is dependent on revenue generation, presumably from paying consumers, it is irrelevant – in terms of financial viability – whether these customers are higher or lower income, or if they are businesses and organizations instead of users. What matters is that the revenues generated can cover the costs of deployment.

Affordability, particularly broadband affordability, on the other hand, is shaped by the consumer profile. So, whereas a deployment may be financially viable from the perspective of a service provider, in that it provides connectivity to higher-income consumers (or businesses), that particular deployment would not be serving an affordability goal.

Figure 34: Financial viability versus affordability



Selection Step 3b: Components of an Appropriate Last Mile Connectivity Solution



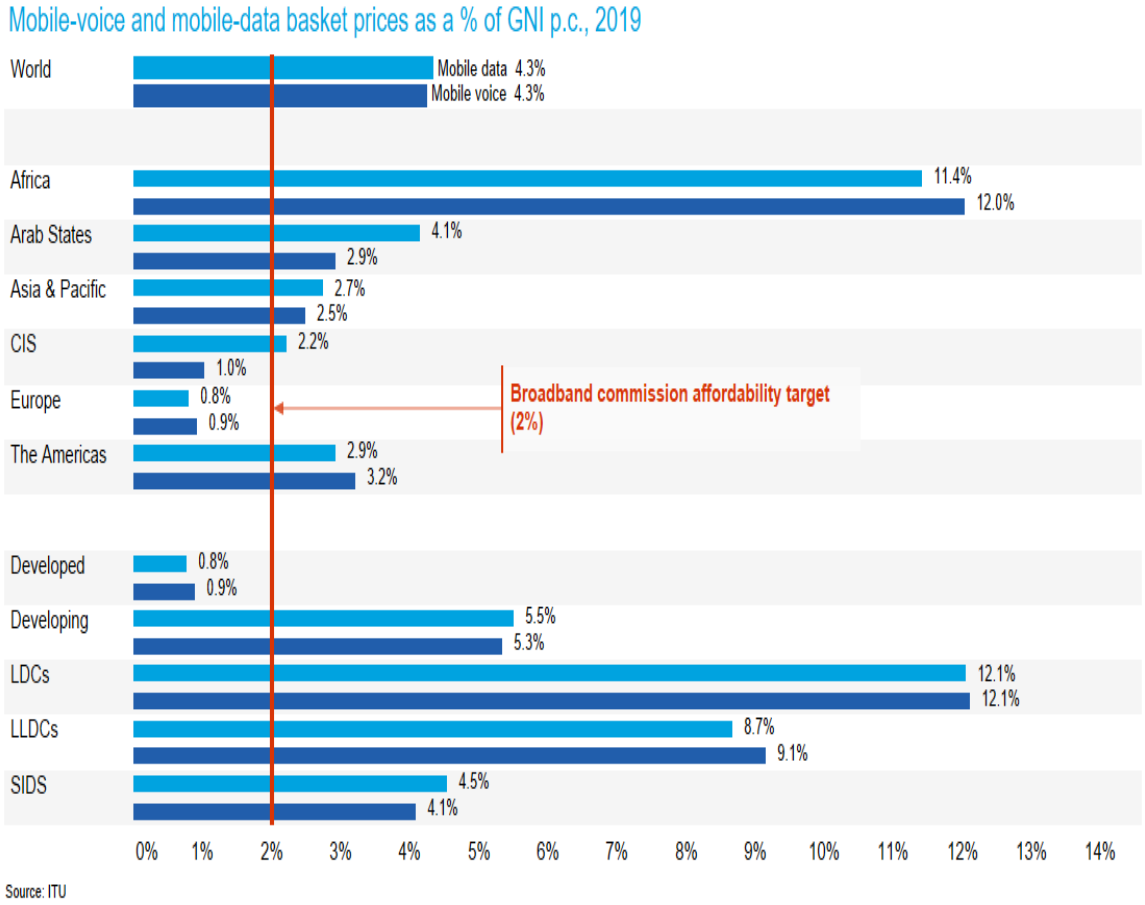
Affordability

As the focus of this Solutions Guide is to encourage last-mile connectivity solutions that deliver affordable Internet to unserved and underserved communities, designing potential solutions begins with identifying what price levels of service would be considered affordable.

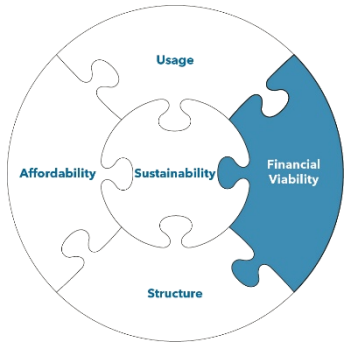
One approach would be to identify affordability thresholds of 2 per cent of monthly GDP per capita, as well as 5 per cent for sensitivity analysis, using national averages.

A more granular approach would consider regional or local average income levels, which can be obtained from national statistical agencies.

The focus on affordability (and on the other critical components highlighted in the selection model, particularly sustainability) emphasizes the importance of ensuring that members of the locality or community – the new service's potential customers – play a role in determining how the new service is established.



Selection Step 3b: Components of an Appropriate Last Mile Connectivity Solution



Financial Viability

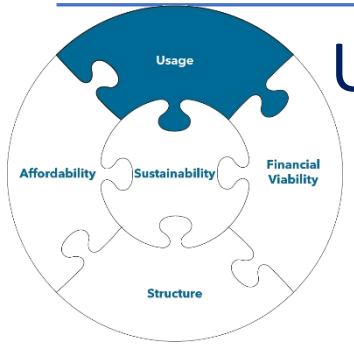
The financial viability of different forms of service provision depends on a number of factors. Affordability thresholds (if applied) and usage requirements (if applied) from the previous sections can serve as inputs for calculating financial viability. They can also be left out, depending on the ultimate goal of the intervention. Financial viability depends on a number of enabling factors and binding constraints, some of which are articulated here.

It is essential to estimate the potential demand for connectivity service in order to determine whether the service will generate sufficient revenue to cover capital investments and ongoing operating expenses. On the supply side, service options will be determined by environmental / geographic limitations, technical considerations, pricing (of backhaul) and regulatory requirements and limitations.

Table 27: Components of financial viability assessments

Considerations of financial viability	Estimating demand	Access network design and technologies	Backhaul limitations
Data components	Per capita income (or ARPU) Community population (or active subscriptions) Census of businesses (enterprise, government, non-profit organizations, etc.)	Geographic area to cover Customer population density Electrical grid availability Regulatory policy considerations (ISP licensing, spectrum use) Financing options (including cost of capital)	Distance to backhaul PoP in some cases Capacity available Cost of bandwidth

Selection Step 3b: Components of an Appropriate Last Mile Connectivity Solution



Usage

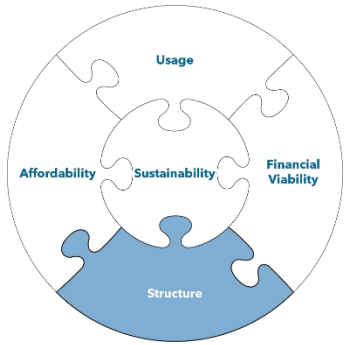
An ex-ante determination of usage for last-mile connectivity service will significantly impact the calculations of the type of service that could be established and what the costs and pricing of that service will be.

It may be that the QoS (and thus general usage) should be determined by whatever the market can support; or, usage could be more prescriptive in that specific activities are required for the last-mile connectivity service, such as providing connectivity for healthcare services (telemedicine), distance learning, government services, etc.

General connectivity service features a wide range of usage levels that are usually constrained by QoS and the price of connectivity. If specific sectoral applications are the focus of the connectivity service, then the QoS that the network needs to support will be determined by the QoS thresholds needed for those applications and services.

Telemedicine participant	Services	Bandwidth
Patient	Video consultation; accessing electronic records	1.5 to 3 Mbit/s
Single-physician practice	Supports practice management functions, e-mail and web browsing; allows simultaneous use of electronic health records and high-quality video consultations; enables non-real-time image downloads; enables remote monitoring	4 Mbit/s
Rural health clinic (approximately 5 physicians)	Supports clinic management functions, e-mail and web browsing; allows simultaneous use of electronic health records and high-quality video consultations; enables non-real-time image downloads; enables remote monitoring; enables HD video consultations	10 Mbit/s
Clinic/large physician practice (5-25 physicians)	Supports clinic management functions, e-mail and web browsing; allows simultaneous use of electronic health records and high-quality video consultations; enables real-time image transfer; enables remote monitoring; enables HD video consultations	25 Mbit/s
Hospital	Supports hospital management functions, e-mail and web browsing; allows simultaneous use of electronic health records and high-quality video consultations; enables real-time image transfer; enables continuous remote monitoring; enables HD video consultations	100 Mbit/s
Academic/large medical centre	Supports hospital management functions, e-mail and web browsing; allows simultaneous use of electronic health records and high-quality video consultations; enables real-time image transfer; enables continuous remote monitoring; enables HD video consultations	1,000 Mbit/s

Selection Step 3b: Components of an Appropriate Last Mile Connectivity Solution



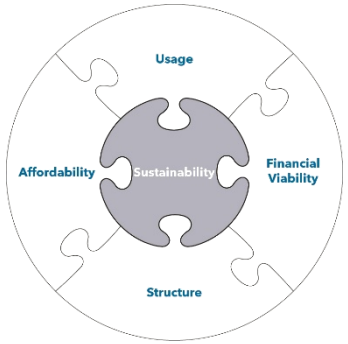
Structure

The structure of the entity delivering service will be determined by the availability of options in the policy and regulatory market environment (see section in Step 2 discussing different categorical classifications). The overall policy and regulatory environment for Internet connectivity in any given country will contribute significantly to either enabling and encouraging new service deployment for unconnected communities, or act as a gating impediment. Depending on the type of last-mile connectivity intervention selected, and on the overall policy environment, different last-mile connectivity intervention types will face different regulatory issues.

Table 31: Regulatory issues by organizational structure

	Commercial MNO	Commercial ISP	Not-for-profit local mobile network	Not-for-profit local ISP network
Regulatory issues	Commercial telecom operation licences required; licensed spectrum rights required	Commercial ISP licence required	Licensed spectrum rights required (except in partnerships with an MNO); telecom licence may be required	ISP licence may be required

Selection Step 3b: Components of an Appropriate Last Mile Connectivity Solution



Sustainability

Sustainability in this context goes beyond revenue modelling to consider the intervention's longer-term viability, ensuring that operating expenditures, future growth and upgrades are taken into account.

Table 32: Sustainability considerations by organizational structure

	Commercial MNO	Commercial ISP	Not-for-profit local mobile network	Not-for-profit local ISP network
Sustainability considerations	Commercial operation that must break even (or provide coverage as a corporate social responsibility endeavour or coverage obligation requirement)	Commercial operation that must break even (or provide coverage as a corporate social responsibility endeavour or coverage obligation requirement)	Usage fees may have to be supplemented with in-kind contributions (network installation and operation) or ongoing community or government subsidies	Usage fees may have to be supplemented with in-kind contributions (network installation and operation) or ongoing community or government subsidies

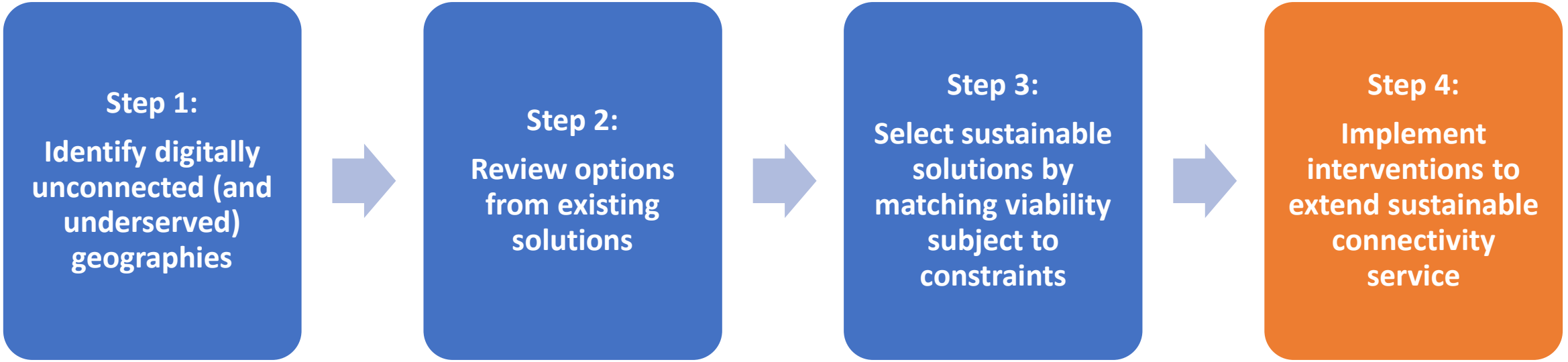
Selection Step 3c: A Decision Matrix for Sustainable Solutions

The range of options facing any single intervention are extensive and the process of filtering the characteristics of the constraints can be linear (e.g. a decision tree) or iterative (determines a good fit on the basis of all of the inputs and constraints unique to each situation).

Table 33: A decision matrix for appropriate sustainable solutions

		Commercial MNO	Commercial ISP	Not-for-profit local mobile network	Not-for-profit local ISP network
Affordability		Ex-ante measure of affordability threshold (such as 2 per cent of monthly GDP per capita for 1 GB of mobile broadband data) applied at national or local level; determination whether this will govern selection process or used just as an external measure of progress			
Usage		Ex-ante determination of usage requirement: will usage be determined by what the market (and financial viability) support, or are there specific services and applications (such as e-government, health or education) that require meeting specific QoS thresholds?			
Financial viability	**Estimating demand and financial viability**	Small population/low income Small population/higher income Larger population/low income Larger population/higher income	Small population/low income Small population/higher income Larger population/low income Larger population/higher income	Small population/low income	Small population/low income Small population/higher income Larger population/low income
	QoS options (backhaul)	High capacity and competitive pricing Low capacity and high pricing	High capacity and competitive pricing	Low capacity and high pricing	Low capacity and high pricing
	Access network characteristics	Small area/flat terrain Large geographic area/flat terrain	Small area/flat terrain Small area/mountainous terrain Large area/flat terrain Large area/mountainous terrain	Small area/flat terrain; Small area/mountainous terrain; Large area/flat terrain	Small area/flat terrain Small area/mountainous terrain Large area/flat terrain Large area/mountainous terrain
Structure		Commercial telecom operation licences required; licensed spectrum rights required	Commercial ISP licence required	Licensed spectrum rights required (except partnerships with an MNO); telecom licence may be required	ISP licence may be required
Sustainability		Commercial operation that must break even (or provide coverage as a corporate social responsibility endeavour or coverage obligation requirement)	Commercial operation that must break even (or provide coverage as a corporate social responsibility endeavour or coverage obligation requirement)	Usage fees may have to be supplemented with in-kind contributions (network installation and operation) or ongoing community or government subsidies	Usage fees may have to be supplemented with in-kind contributions (network installation and operation) or ongoing community or government subsidies

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)

4d: Options for interventions – Examples of Recurring financing

Limited concessional financing support can serve to de-risk private sector investment (as described as a smart subsidy).

Table 37: Recurring subsidy interventions and their applicability to different last-mile connectivity models

Recurring subsidy interventions	Examples	Commercial MNO	Commercial ISP	Not-for-profit local mobile network	Not-for-profit local ISP network
Collect and distribute universal service funds for recurring subsidies to de-risk deployments	Malaysia's Universal Service & Access Fund provided support for the deployment of the six main initiatives in the National Broadband Initiative; Gabon's experience using its universal service fund to finance network expansion and operations for 2 700 remote villages in areas deemed too unprofitable for private telephony operators (see LMC case study); South Africa's experience utilizing recurring subsidies from the South African Universal Services Fund to provide free Wi-Fi to rural schools and clinics (see LMC case study)	✓	✓	✓	✓
Consider more flexible and beneficial tax arrangements for non-profit local complementary networks				✓	✓

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)

Thank you for your participation !