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MINISTERSTVO PRŮMYSLU A OBCHODU

Definition of the investment gap in the roll-out of VHCN networks in relation to the development of 5G networks

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Contents

Abbreviations

Abbreviation	Description
5G	5th generation of mobile communications
MIMO	An abstract mathematical model for a multi-antenna wireless network, standing for Multiple Input Multiple Output
AMEI	Call for investment commitments, French: l'Appel à manifestation d'engagement d'investissement
BEREC	Association of European Regulators in the Field of Electronic Communications, known in English as the Body of European Regulators for Electronic Communications
BoR	Board of Regulators
BTS	Base Transceiver Station
CATV	cable television, from 'community antenna television'
CD78	Yvelines Departmental Council, French: Conseil Départemental des Yvelines
CEF 2	Connecting Europe Facility
CZK	Czech koruna
CR	Czech Republic
Czech Statistical Office	Czech Statistical Office
DDPP	Digital Decade 2030 programme, in English: Digital Decade policy programme 2030
DESI	Digital Economy and Society Index
DOCSIS	Data Over Cable Service Interface Specification
EECC	European Electronic Communications Code
EC	European Commission
ESD	Electronic data collection
EU	European Union
EUR	Euro
FST	Just Transition Fund
FTTB	Fibre to the Building (to a block of flats with multiple residential units)
FTTC	A type of fibre-optic connection where the fibre terminates in an outdoor distribution cabinet (or pole), known as 'Fibre To The Curb'
FTTH	Fibre to the Home (apartment), in English: FTTB
FTTH-GPON	Gigabit Passive Optical Network for FTTH
FTTN	Hybrid access network (Fibre to the Node)
FTTx	A general term for all types of broadband network architecture, 'Fibre to the "x"'
FWA	Fixed Wireless Access
FWE-5G	Future Wireless Ecosystems – 5G
GIA	Gigabit Infrastructure Act
GO	
GPS	Global Positioning System
IoT	Internet of Things
IP	Internet Protocol
IROP	Integrated Regional Operational Programme

CZK	Czech koruna
KPIs	Key performance indicators
m, km	metre, kilometre
Mbit/s, Gbit/s	Megabits per second, Gigabits per second
MIMO	an abstract mathematical model for a multi-antenna wireless network, from the English ‘Multiple Input Multiple Output’
MPO	Ministry of Industry and Trade
NBF	National Broadband Fund, but I don’t think that abbreviation exists; probably Bredbåndspuljen
NGA	Next Generation Access Network
NPO	National Recovery Plan
OBAM	Residential Building Address Points
OP PIK	Operational Programme ‘Entrepreneurship and Innovation for Competitiveness’
OP TAK	Operational Programme: Technology and Applications for Competitiveness (OP TAK)
Passive OAN	Passive optical access network
PoP	Point of Presence
QAM	Quadrature amplitude modulation
QGIS	Quantum Geographic Information System (GIS)
Recovery and Resilience Plan – RRP	
RO-NET	Project to provide high-speed broadband internet coverage in rural areas of Romania
RÚIAN	Register of Territorial Identification, Addresses and Real Estate
SIRO	
Community	Local Residents’ Initiative
thousand, million, billion	thousand, million, billion
UNICO	Programme for the Universalisation of Digital Infrastructure for Cohesion, in Spanish: Programa de Universalización de Infraestructuras Digitales para la Cohesión
VHCN	Very High Capacity Networks
WAS/RLAN	Wireless Access Systems (WAS), comprising Radio Local Area Networks (RLAN)
ZSJ	Basic Settlement Unit

1 Executive Summary

This study was prepared to determine the investment gap required to achieve digital connectivity targets in the Czech Republic, with an emphasis on high-capacity network (VHCN) coverage and the roll-out of 5G networks. The aim was to describe the level of investment required to cover individual areas depending on the type of technology selected, specifically FTTx optical technology and FWA wireless technology. The study's findings serve as a basis for the Ministry of Industry and Trade's decisions on further funding and subsidies in the field of digital infrastructure.

The analysis is based on seven connectivity scenarios (S1–S7), which model the costs and scope of the infrastructure required to achieve national and transnational targets for VHCN coverage of households. For the final comparison, two scenarios were selected for detailed analysis in terms of their financial costs, the required length of the fibre-optic network, coverage of individual basic settlement units (ZSJ), and the ability to cover households in remote areas. The calculation took into account both access networks and backhaul capacity, using demographic data to quantify the costs associated with network deployment. These were scenarios 2 and 7:

- Scenario 2: 95% coverage using FTTx technology only.
- Scenario 7: 95% coverage using a combination of FTTx and FWA.

The analysis of the scenarios showed that Scenario 2, focused on FTTx optical technology, offers the highest quality and stability of connection, but at the cost of higher investment expenditure, with an investment gap of CZK 61.5 billion. In contrast, Scenario 7 combines FTTx and FWA, which reduces total costs by approximately 14 per cent to less than CZK 53 billion and accelerates coverage in less densely populated areas. Scenario 7 thus represents a more flexible and cost-effective option, enabling rapid deployment in rural areas with lower population density.

The analysis also identified an investment gap for connecting backhaul networks in small settlement areas that are not yet connected. The results show that 1,206 small settlement areas remain unconnected in the Czech Republic, representing 1.56 per cent of households, or approximately 80,500 households. To fully connect these ZSJ using FTTx technology, it would be necessary to build approximately 2,054 km of optical infrastructure at an estimated cost of 1.7 billion CZK.

Management summary

This study was conducted to identify the investment gap required to achieve digital connectivity targets in the Czech Republic, with a focus on high-capacity network (VHCN) coverage and the development of 5G networks. The aim was to describe the level of investment required for coverage in each area, depending on the type of technology selected, namely FTTx optical technology and FWA wireless technology. The results of the study serve as a basis for the Ministry of Industry and Trade to make decisions on further funding and subsidies in the field of digital infrastructure.

The analysis is based on seven connectivity scenarios (S1–S7) that model the cost and scale of the infrastructure required to achieve national and supranational VHCN household coverage targets. The two scenarios analysed in detail in terms of their financial costs, the required length of the fibre network, the coverage of each LSU (basic settlement unit) and the ability to cover households in remote areas were selected for final comparison. The calculation took into account both access network and backhaul capacity, using demographic data to quantify the costs associated with network construction. These were scenarios 2 and 7:

- Scenario 2: 95 per cent coverage using FTTx technology only.
- Scenario 7: 95 per cent coverage using a combination of FTTx and FWA.

Analysis of the scenarios showed that Scenario 2, which focuses on FTTx optical technology, offers the highest quality and stability of connectivity, but at the cost of higher investment expenditure, with an investment shortfall of CZK 61.5 billion. Scenario 7, on the other hand, combines FTTx and FWA, reducing the overall cost by around 14 per cent, to less than €53 billion, whilst accelerating coverage in less populated areas. Scenario 7 therefore represents a more flexible and cost-effective option that enables rapid deployment in rural areas with lower population density.

The analysis has also identified an investment gap for connecting backhaul networks in WUAs that are not yet connected. The results show that 1,206 ZSJs remain unconnected in the country, representing 1.56 per cent of households, or approximately 80,500 households. To fully connect these WUAs using FTTx technology, around 2,054 km of fibre-optic infrastructure would need to be built at an estimated cost of CZK 1.7 billion.

2 Introduction

The aim of the analysis is to determine wholesale prices, both for network handover points to the backhaul and for household connections (OBAM/flat[1]), and to define the investment gap in the roll-out of VHCN networks, with an emphasis on the potential use of FWA and increasing the capacity of 5G technologies. The first part of the analysis focuses primarily on a synthesis of previously published data and information relating to the topic, the establishment of a methodology, the relevance of the topic in terms of the Czech Republic's (and, by extension, the EU's) objectives, and a proposal for a model to calculate the investment gap required to meet these objectives. The aim of the second part is to quantify the costs of the investment gap and to conduct a sensitivity analysis of the costs associated with household coverage targets, including an estimate of the concentration curve and a calculation of cost categories. The study contains an analysis and recommendations in the following areas:

- A technical and economic analysis of connecting OBAM via a fibre-optic network or similar VHCN technology.
- Determination of the parameters for the model used to calculate the investment gap in the roll-out of VHCN networks, so as to achieve the Digital Decade targets (formerly DESI).
    - Determination of population density parameters and the costs of implementing handover points.
    - Determination of demographic data (characteristics of administrative districts/municipalities by address points) and their correlation with network capacity requirements in connection with the transition to VHCN networks.
- Description and general recommendations for an investment model to meet the DESI targets.
- Updating the calculation of the investment gap for VHCN networks in the context of 5G.

2.1 Regulatory framework

The 'Digital Decade' policy programme sets out digital ambitions for the coming decade. The main objective in the context of this study, arising from this programme, is 'universal broadband coverage with speeds of at least 100 Mbit/s, with the possibility of upgrading to gigabit speeds by 2025' and 'gigabit connectivity for all by 2030'. The following documents are key to achieving this objective:

In the context of European legislation:

- REGULATION (EU) 2024/1309 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL[2] on measures to reduce the costs of deploying gigabit electronic communications networks, amending the Regulation (hereinafter referred to as 'GIA')
- Decision (EU) 2022/24813 of the European Parliament and of the Council[3] on the 'Digital Decade 2030' policy programme (hereinafter referred to as 'DDPP').

In the context of the Czech Republic:

- National Plan for the Development of NGA Networks
- Act No. 194/2017 Coll., on measures to reduce the costs of deploying high-speed electronic communications networks and amending certain related acts
- Act No. 127/2005 Coll., on electronic communications and amending certain related Acts, which transposes the applicable regulatory framework of the European Union, replaced Act No. 151/2000 Coll.,
- Strategic Plan: The Digitalisation of the Czech Republic by 2030

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[1] The term 'OBAM/flat' is used to calculate the total number of households; see Chapter 2.2.1.3.

[2] REGULATION (EU) 2024/1309 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 29 April 2024, available online here: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32024R1309

[3] EUROPEAN PARLIAMENT AND COUNCIL. Decision (EU) 2022/2481 of the European Parliament and of the Council. Available online here: https://eur-lex.europa.eu/legal-content/CS/TXT/?uri=CELEX:32022D2481

2.2 Current situation

A number of studies have been carried out in the past focusing on defining and quantifying the investment gap. In this chapter, we summarise the key information. It should also be noted at the outset that the market for electronic communications networks and services is a dynamically evolving sector and, alongside technological developments and changes in consumer behaviour, there is a rapid increase in data consumption and the resulting demands on connectivity technology.[4] This development is well illustrated by the update to connectivity targets, whereby, from 2022, KPIs will no longer be derived from NGA coverage but from very high-capacity networks (VHCNs) – that is, networks meeting technical standards ensuring high-speed connectivity with sufficient capacity to meet both current and future data transmission demands.

Since 2015, the European Commission has regularly monitored the digital competitiveness of individual Member States through the Digital Economy and Society Index (hereinafter 'DESI'), which was integrated into the European Digital Decade Programme (DDPP) in 2023. In 2024, the EC published its second 'State of the Digital Decade' report[5], which provides a comprehensive overview of the progress made towards achieving the digital targets and objectives set for 2030 (under the DDPP). The report emphasises the need for further investment in infrastructure development and broadband connectivity; in the case of the Czech Republic, connectivity is the weakest aspect of the assessment, and the country ranks near the bottom of the index (19th out of 27) among EU countries. Defining the investment gap is therefore one of the fundamental tools for addressing sub-optimal investment situations and compensating for market failures.

Although, according to the latest available DESI report, there has been a significant improvement in connectivity, specifically in ultra-high-speed broadband (UHSB) access, coverage remains a problematic area. In terms of UHSB coverage, the Czech Republic stands at 50.7 per cent of households covered, compared with the European average of 73 per cent. In terms of VHCN coverage in rural areas, the Czech Republic is one of the lowest-ranked countries, with household coverage at just 8 per cent compared to the EU average of 45 per cent. One of the key priorities is to improve the connectivity indicator score, which, in the context of this study, involves establishing a clear definition of the investment gap and identifying the areas and scale of support required.

In terms of the level of investment required for an available connection, it is clear that providers will invest where the cost of providing an available connection is not high (or even extreme), and where there is a high level of demand from users. However, it cannot be expected that the national target (KPI) of the Czech Republic's Strategic Plan for Digitalisation (to ensure gigabit network coverage at the point of delivery for 95 per cent of households by 2030) will be achieved without well-thought-out support for the private sector and initiatives to build connections.

According to a study carried out in 2020, *'Analysis of the Remoteness of Handover Points for Access Network Connection Sections'*, the investment gap based on the remoteness parameter was described as follows: *to quantify the investment gap, the study identified the need to build approximately 3,068 km of optical networks to cover remote ZSJs. The average distance per ZSJ is 1.61 km, with a maximum required length of up to 6.12 km.*

According to the 2021 National Plan for the Development of Very High-Capacity Networks, the investment gap for connecting addressable locations to VHCN networks was determined such that, by the end of the 2021–2027 programming period, 470,000 connections to dwellings would not be built or upgraded under commercial conditions: *"The actual investment gap totals 15.3 billion CZK. If we were to base our calculations on this figure for total eligible expenditure (CZV) of CZK 15.3 billion and assume an average support rate of 75 per cent, then, when calculating using this average support rate of 75 per cent of eligible costs, subsidy support from public funds amounting to approximately CZK 11.5 billion will be required for these activities"*[6] . The 2019 analysis of the state of NGA network development, which also analysed the costs associated with connecting all addressable locations, projected the investment gap in 2019 as follows: *If we were to assume an average investment of 30,000 CZK per available connection, the current investment gap required to cover the remaining number of dwellings with fibre-optic connectivity amounts to approximately 97 billion CZK (3.2 million dwellings multiplied by 30,000 CZK).* However, the analysis assumed at least a 5% increase in commercially built fibre-optic networks.

Furthermore, there are municipalities in the Czech Republic (numbering in the single digits of a per cent) where, even with 100 per cent subsidy support (i.e. with no private funding), operating revenues will never be sufficient to cover operating costs

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[4]https://digital-strategy.ec.europa.eu/en/library/results-european-data-market-study-2021-2023 f

[5]https://digital-strategy.ec.europa.eu/en/news/second-report-state-digital-decade-calls-strengthened-collective-action-propel-eus-digital

[6]https://www.mpo.gov.cz/cz/e-komunikace-a-posta/elektronicke-komunikace/koncepce-a-strategie/narodni-plan-rozvoje-siti-nga/narodni-plan-rozvoje-siti-s-velmi-vysokou-kapacitou--259858/

costs. For such municipalities, it will be necessary to establish a special scheme, for example via FWA or another wireless connection, capable of providing services to end-users at a quality meeting the performance thresholds of VHCN networks, even during peak periods. As part of this study, we will, for the first time, focus on scenarios that would lead to the fulfilment of national coverage targets, including through the use of FWA connections, and quantify the costs associated with this option.

2.2.1 Basic definitions of terms

2.2.1.1 Definition of VHCN networks

VHCN networks are key to providing end-users with very high-quality services; they support the EU's objectives regarding the roll-out and use of high-capacity networks. These networks enable advanced internet services, enhance digital competitiveness and support the ambition to achieve a European gigabit society. When describing VHCN networks, we draw on the definition set out in the European Electronic Communications Code, as clarified by the BEREC Directive[7] which sets out specific criteria for VHCN.

Definition according to the Code: *'An electronic communications network consisting entirely of optical elements at least up to the distribution point at the service location, or an electronic communications network capable, under normal conditions at peak times, of achieving similar performance in terms of available downlink and uplink bandwidth, resilience, parameters relating to error rates and latency, including fluctuations in these parameters. Network performance may be considered similar regardless of whether the end-user's perception differs due to distinct characteristics arising from the nature of the medium through which the network is ultimately connected to the network termination point."*

VHCN Categories

According to BEREC BoR Guidelines (23) 164[8],for a network to be designated as a VHCN of a given category, the conditions associated with that category must be met for at least 95 per cent of the addresses in the network. This means, for example, that 95 per cent of the addresses in the network are connected via an optical network.

Table 1: VHCN categories

VHCN categories	VHCN code
Not covered by VHCN.	0
Fibre connected to the address level.	1
Fibre connected to the base station level (relevant for FWA).	2
The fibre is not connected at the address level, but the power thresholds for criterion 3 of the VHCN Directive have been met.	3
The fibre is not connected at the base station level, but the power thresholds for criterion 4 of the VHCN Directive have been met (relevant for FWA).	4

VHCN technology
In this study, we are focusing for the first time on VHCN network coverage not only from the technological perspective of optical networks (FTTx), but also on the possibility of extending coverage to remote areas using technologies of a similar quality, in particular FWA technology. When calculating FTTx costs, we will take into account the connection technology in the relevant service area.

FTTx (Fibre to the x) – FTTx technologies comprise various types of optical access networks that use optical fibres to transmit data. They are distinguished by the location to which the optical fibre extends. The specific location thus presents a number of differences which, taken together, can have a significant impact on the total size of the investment gap.

Types of FTTx Technologies

[7]https://www.berec.europa.eu/en/document-categories/berec/regulatory-best-practices/guidelines/berec-guidelines-on-very-high-capacity-networks

[8]https://www.berec.europa.eu/system/files/2023-10/BoR%20%2823%29%20164%20FNE%20WG_Draft%20BEREC%20Guidelines%20on%20VHCNs.pdf

1. **FTTH (Fibre to the Home):** The optical fibre is routed directly to the home. This architecture provides the highest speed and quality of connection, as the optical fibre extends all the way to the end user.

Advantages	Disadvantages
Maximum transmission speed and minimum latency.	Higher installation and maintenance costs compared with other FTTx technologies, particularly in densely populated or remote areas.

2. **FTTB (Fibre to the Building):** The optical fibre is routed to a building, such as a block of flats or an office block. Inside the building, the signal is distributed using copper cables or other technologies.

Advantages	Disadvantages
High transmission speeds and lower installation costs compared to FTTH, as the optical fibre is not routed all the way to individual units within the building.	Performance may be affected the quality and the length of the metallic cables inside the building.

3. **FTTC (Fibre to the Curb):** The optical fibre is routed to a point close to the end user, for example to the street or a distribution cabinet serving several houses. From this cabinet, the signal is distributed via metallic cables.

Advantages	Disadvantages
Lower installation costs compared to FTTH and FTTB, as the optical fibre is not routed directly to individual buildings or houses.	Transmission speed and latency may be affected by the quality and length of the copper cables between the distribution cabinet and the end user.

4. **FTTN (Fibre to the Node):** The optical fibre is routed to a node, which may be several kilometres from the end user. From this node, the signal is distributed via metallic cables.

Advantages	Disadvantages
Lowest installation costs compared to other FTTx technologies, as the optical fibre is not routed close to end users.	Significantly lower transmission speeds and higher latency due to the long distance the signal must travel via metallic cables.

FWA

FWA architecture differs from that of fixed networks due to the inherent characteristics of wireless connectivity. FWA technology is divided into licensed-spectrum FWA and unlicensed-spectrum FWA. End-users regard FWA networks as a substitute for 'traditional' fixed-line solutions, as they receive similar services via the FWA infrastructure.

In accordance with the principle of technological neutrality, both fixed and FWA architectures can be used to provide fixed services, and it is possible to achieve VHCN parameters using this technology. FWA technologies can make a significant contribution to achieving the EU's objectives under DESI and the broader vision *of the Gigabit Society* by providing fast and reliable internet connectivity at a fraction of the cost of building fixed/fibre networks.

BEREC VHCN Network Criteria

According to BEREC guidelines and Article 2(2) of the EECC, a network must meet the following criteria to be considered a VHCN network:

- **Criterion 1**
  Fixed fibre-to-the-building network: Any network providing a fixed connection with fibre-optic cabling extending at least to a building containing multiple residential units.
- **Criterion 2**
  Wireless network with fibre-optic cables extending to the base station: Any network providing a wireless connection with fibre-optic cabling extending to the base station.
- **Criterion 3**

Network providing a fixed connection with equivalent performance: Any network providing a fixed connection that is capable, under normal conditions at peak times, of delivering a quality of service defined by the following parameters (performance thresholds 1):

- Data transfer rate (downlink) ≥ 1000 Mbit/s
- Data transfer rate (uplink) ≥ 200 Mbit/s
- IP packet loss rate (Y.1540) ≤ 0.05%
- IP packet loss rate (Y.1540) ≤ 0.0025%
- Bidirectional IP packet delay (RFC 2681) ≤ 10 ms
- IP packet delay variation (RFC 3393) ≤ 2 ms
- IP service availability (Y.1540) ≥ 99.9% per year

- **Criterion 4**
  A network providing wireless connectivity with equivalent performance: Any network providing wireless connectivity that is capable, under normal conditions during peak times, of delivering a quality of service defined by the following parameters (performance thresholds 2):

  - Data transfer rate (downlink) ≥ 350 Mbit/s
  - Data transfer rate (uplink) ≥ 50 Mbit/s
  - IP packet loss rate (Y.1540) ≤ 0.01%
  - IP packet loss rate (Y.1540) ≤ 0.01%
  - Bidirectional IP packet delay (RFC 2681) ≤ 18 ms
  - IP packet delay variation (RFC 3393) ≤ 5 ms
  - IP service availability (Y.1540) ≥ 99.9% per year

2.2.1.2 ZSJ

A basic settlement unit (BSU) is defined as a unit representing parts of a municipality's territory with distinct spatial, technical and urban planning characteristics, or catchment areas comprising groups of residential or recreational buildings. A basic settlement unit is a constituent part of the settlement structure and is intended for the spatial identification and monitoring of socio-economic and spatial-technical phenomena directly linked to settlement, in particular the results of the census of the population, houses and dwellings. The ZSJ code is a unique numerical spatial identifier for the ZSJ territorial unit; it is determined using the same procedure as the ZSJ name, is fixed and is unique within the Czech Republic.

2.2.1.3 OBAM

Address points of residential buildings (OBAM) are defined as address points which:

- belong to a building with a land-use code according to the RÚIAN classification:
  - residential building (3)[9]
  - apartment block (6)
  - detached house (7)
  - accommodation facility (11)
- belongs to a building with a use code according to the RÚIAN classification: 19 (other building) and has at least one flat according to RÚIAN
  - other building (19)
- belongs to a building without an assigned use code, but has at least one flat according to RÚIAN.

2.2.1.4 Household

In view of DESI reporting, we have decided to focus primarily on the concept of a household for this analysis. In light of the last point mentioned, it is also necessary to address the issue of reporting and comparison within the EU (benchmarking). In the case of the latest report for 2023[10], for example, the number of households in the Czech Republic for 2023 relates to

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[9] RÚIAN codes

[10] https://digital-strategy.ec.europa.eu/en/library/digital-decade-2024-broadband-coverage-europe-2023

to the corresponding CSO figure for 2021, which stood at 4,813,103. This data includes the OBAM/flat categories[11] . In our forecast, we therefore use an updated figure for the number of households, comparable to the number of so-called OBAM/flats. For the Czech Republic, we use a figure of 5,146,935 households.

2.2.1.5 ZSJ colour

The ZSJ colour indicates the ratio of occupied address points with at least one available connection to the total number of occupied address points in the ZSJ. Below is an explanation of the ZSJ colour classification according to the criteria for determining the colour based on the coverage of address points in residential buildings (OBAM):

White: White areas are those in which there is no broadband infrastructure and where it is unlikely that any will be developed in the near future. White NGA areas are areas without an NGA network, where it is unlikely that one will be built on a commercial basis within 3 years:

- NGA network coverage ≤ 40%
- NGA network coverage ≤ 50% using at most one technology

Grey: Grey areas are those in which a single network operator is present and it is unlikely that another network will be established in the near future. Public support in these areas is possible if market failure can be demonstrated and subject to certain compatibility conditions. A grey NGA area is one where only one such network exists (or is under construction) and no private company plans to build another within the next three years

- NGA network coverage > 50% by a maximum of one operator
- NGA coverage > 40 per cent by a maximum of one operator and, at the same time, using more than one technology

Black:

- NGA network coverage > 50 per cent by more than one operator
- NGA network coverage > 40% using more than one technology and provided by more than one operator

2.3 Current support programmes and their results

The development of VHCN connectivity is closely linked to public funding. The roll-out of networks and connections to households is therefore the subject of operational programmes managed by the Ministry of Industry and Trade. Funding is expected to be drawn from several sources: the Integrated Regional Operational Programme (IROP) 2021–2027, the Connecting Europe Facility (CEF 2), the Digital Europe Programme, the Just Transition Fund (JTF), InvestEU and the Recovery and Resilience Facility.

2.3.1 Operational Programme ‘Technologies and Applications for Competitiveness’ (OP TAK)

The Operational Programme ‘Technologies and Applications for Competitiveness’ (OP TAK)[12] is aimed at supporting the roll-out of high-speed internet in areas with insufficient coverage. The first call for proposals, launched by the Ministry of Industry and Trade, focuses on building new networks and modernising existing ones.[13] Projects can receive funding of up to 228 million CZK, with eligible costs including expenditure on infrastructure, cabling and construction work. The total amount of allocated funds is 4 billion CZK and the call for proposals is open from 1 August to 31 December 2024. Physical implementation must be completed by June 2029[14] .

(11) The term‘OBAM/flat’ can therefore be used interchangeably with the term ‘household’.

[12] https://www.mpo.gov.cz/cz/podnikani/dotace-a-podpora-podnikani/optak-2021-2027/

[13] https://www.verejnakonzultace.cz/i-vyzva-op-tak/

[14] https://www.mpo.gov.cz/cz/podnikani/dotace-a-podpora-podnikani/optak-2021-2027/

Results: ongoing.

2.3.2 National Recovery Plan (NPO)

This funding is provided under the National Recovery Plan (NRP)[15] , with a specific focus on supporting the connection of premises to very high-capacity networks (VHCN). The aim of the call is to support the roll-out of very high-capacity networks that will enable access to fast and reliable electronic communications, particularly in areas where market-based solutions are not viable, i.e. primarily in rural areas. The programme is funded from the European Union budget through the Recovery and Resilience Facility (RRF). The call's allocation amounted to CZK 3.466 billion, and the maximum grant amount for an individual project is CZK 230 million, with the grant covering up to 80 per cent of the project's eligible expenditure. The aim of the call was to build VHCN networks in areas where connections with sufficient speeds (e.g. less than 30 Mbit/s) are not available, with a focus on rural areas where commercially viable market solutions do not exist and where intervention through public funding is necessary. This call for proposals was announced on 14 April 2022. The acceptance of grant applications began on 28 April 2022, and the deadline for submissions was set for 31 August 2022.

Results: According to the results published on the website of the Broadband Competence Office of the Czech Republic (BCO), a decision was issued in 2023 to award grants to 330 service areas, covering a total of 32,669 addresses.

2.3.3 Operational Programme 'Entrepreneurship and Innovation for Competitiveness' (OP PIK)

The Operational Programme 'Entrepreneurship and Innovation for Competitiveness' (OP PIK)[16]provides grants for the development of high-speed internet in the Czech Republic; the funding was divided into two calls: Call II and Call IV.

- Under Call II of this programme, funding was announced for the construction and modernisation of networks, focusing primarily on areas with inadequate connectivity. Businesses may apply for funding for infrastructure projects aimed at improving internet access and enhancing the competitiveness of the business environment. Call II targets so-called 'white spots', where high-speed internet is not available. A total of 1 billion CZK has been allocated to the call, with the provision that the allocation will be increased accordingly should there be significant interest. The call was aimed at businesses (both natural and legal persons), which may apply for a grant towards the equipment and works required to build modern telecommunications infrastructure. Support amounts to 75 per cent of the project's eligible expenditure. The minimum amount of support is 0.5 million CZK, and the maximum is 200 million CZK.
- Under the fourth call for proposals of the OP PIK programme, CZK 1.05 billion has been earmarked to support the roll-out of high-speed internet. The aim of the call is to develop next-generation access networks (NGA) in areas with insufficient coverage, where no network offering a minimum speed of 30 Mbit/s is available. The funding was earmarked for the construction, modernisation and expansion of infrastructure and is intended for businesses and electronic communications service providers.

Results: During the second and fourth calls for proposals under the OP PIK, 246 and 112 ZSJ were covered respectively. Most grant award decisions were made in 2023. In terms of technological solutions, the funding covered 243 FTTx projects and 116 FWA projects.

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[15]https://www.mpo.gov.cz/cz/podnikani/narodni-plan-obnovy/vyzvy/i--vyzva-digitalni-vysokokapacitni-site-z-komponenty-1-3-narodniho-planu-obnovy--267008/

[16]https://www.mpo.gov.cz/cz/podnikani/dotace-a-podpora-podnikani/oppik-2014-2020/aktualni-informace/podporene-projekty-zrychli-internet-pro-47-tisic-bytu--261480/

3 Investment models in the EU

In this chapter, we provide an overview of investment models for supporting VHCN connectivity across EU countries.

3.1 EU Country Benchmark

Study of regulatory incentives for the roll-out of VHCN – https://www.visionary.lt/wp-content/uploads/2022/02/Study-on-Regulatory-Incentives-for-the-Deployment-of-Very-High-Capacity-Networks-in-the-Context-of-the-Revision-of-the-Commissions-FINAL-REPORT.pdf

Examples:

UHBN and FTTx coverage is not always at the same level; within the DESI rankings, this is due to the inclusion of the older DOCSIS 3.1 technology, which meets UHBN requirements in certain cases where the technological transition to fibre is still underway.

Sources:

- Digital Decade 2024[17]
- European Broadband Awards archive[18]

3.1.1 Denmark

Denmark ranks among the best countries in the EU in terms of the quality of internet coverage. In the DESI 2022 rankings, Denmark took first place in the overall assessment and, with 97.2 per cent of households covered by VHCN networks, significantly exceeds the EU average (78.8 per cent)[19] .

In 2021, Denmark drew up a new strategy aimed at providing all households and businesses with internet speeds of at least 100 Mbit/s download and 30 Mbit/s upload, whilst also ensuring that 98 per cent of households and businesses have access to internet speeds of up to 1 Gbit/s download by 2025[20] .

Denmark plans to achieve these targets through the roll-out and improvement of networks based on market principles and technology-neutral regulation. At the same time, it is seeking to simplify administrative processes and increase support for operators, for example through public grants under the National Broadband Fund, which focuses on supporting rural areas that are not commercially viable. Under this fund, 145 regional projects worth approximately €8.6 million were funded in 2023, targeting 1,706 households with inadequate internet coverage.

During the COVID-19 pandemic, demand for high-speed internet connections increased. The number of internet subscriptions with speeds of at least 1 Gbit/s rose from 2.2% to 19.8% during this period.

Based on the data observed and the national strategy, Denmark is very well prepared to provide VHCN services on a nationwide basis. However, demand for these services is much lower than the country's technical capabilities. Main

[17] https://digital-strategy.ec.europa.eu/en/library/digital-decade-2024-country-reports

[18] https://digital-strategy.ec.europa.eu/en/library/european-broadband-awards-archive

[19] https://ec.europa.eu/newsroom/dae/redirection/document/106702

[20] https://digital-strategy.ec.europa.eu/en/policies/desi-denmark

The strategy therefore continues to focus on expanding high-speed services through market incentives and by improving conditions for both operators and end-users via the State Support Scheme for Local Authorities, which is designed to boost the roll-out of these services at local authority level.

Djursland[21]

In 2019, the Djursland region utilised approximately EUR 1.5 million from the NBF to build a more modern broadband network. The project arose from an initiative by local residents and was subsequently approved and supported by the state fund. The project covered 14 villages and neighbourhoods in the Djursland area (a total of 500 addresses), where the network was upgraded. According to the local organisers, this step will significantly increase the area's appeal to both residents and businesses.

3.1.2 France

France's broadband internet coverage exceeds the EU average. According to the 2024 DESI ranking, VHCN and FTTP coverage stands at 81.4 per cent of all households, with a steady annual increase. As regards subscriptions with speeds of at least 1 Gbit/s, France stands at 51.6 per cent, placing it at the top of the EU rankings[22] .

The French telecommunications regulator, Arcep, in collaboration with the operator Orange, has drawn up a plan for a complete transition to fibre-optic networks from older technologies (copper, cable) by 2030, which is in line with the Digital Decade's timeline for the roll-out of VHCN. Part of this process involves ensuring transparency regarding information and planned technology transitions, as well as ensuring that the new technology is available sufficiently in advance of the announcement of the phase-out of the old technology.

France – High-Speed Internet Plan [23]

This decentralised project supports local 'smaller' projects, coordinates them in line with the current national strategy for the development of high-speed network infrastructure, and mobilises private operators and local authorities to roll out new high-speed networks across the whole country. Most urban areas will be covered by private operators and companies, reaching 57 per cent of addresses in these areas, which will lead to the roll-out of FTTH in more than 3,800 municipalities. Rural and more remote areas are covered by local authorities, which are supported by both the state and EU grants. Their aim is to cover 38 per cent of households, businesses and public facilities across the country, in more than 28,000 municipalities. Private operators plan to cover the remaining 5 per cent (approximately 3,500 municipalities), including in rural and remote areas. The total estimated cost of the project is €36 billion, comprising funding from private institutions, state support and European funds.

The plan to modernise network coverage also includes a target of 100% FTTP coverage (which will also enable VHCN across the country) by 2025. Compared with the EU target, which has been set for 2030, France would thus be well ahead. Given the current pace of FTTP roll-out, this plan appears feasible; however, the final few per cent of coverage are always the most critical, as these are mostly remote or hard-to-reach locations.

High-speed connectivity for residents of Yvelines [24]

This project in the Yvelines region, west of Paris, forms part of the national strategy for the development of high-speed network infrastructure. Due to its sparse population, this area was not particularly attractive or a viable investment opportunity for private operators. For this reason, the local authorities and the Conseil Départemental des Yvelines (CD78) drew up a digital development plan to provide coverage for approximately 100,000 addresses across 158 municipalities. By the end of 2021, 93,000 households had been connected.

An interesting aspect of this project is its method of financing, whereby the local operator, Seine-et-Yvelines Numérique, was commissioned to build a new network under the AMEI model. This legal and financial model enables a private

[21] https://ruraldigital.eu/2020/01/20/cora-pilots-1-5-million-eur-from-the-danish-national-broadband-pool-to-djursland/

[22] https://ec.europa.eu/newsroom/dae/redirection/document/106701

[23] https://agence-cohesion-territoires.gouv.fr/france-tres-haut-debit-53

[24] https://digital-strategy.ec.europa.eu/en/library/high-speed-broadband-all-yvelines-france

the operator to roll out and manage a high-speed network using its own resources, with a sustainable business plan and within the timeframe set by the local authority. In cooperation with the authorities, the operator selected TDF, which carried out the actual roll-out of fibre-optic cables to the municipalities and thereby acquired a stake in the resulting network. Thanks to state support and favourable conditions for the operator and the private investor (TDF), what was previously an unattractive area has thus become an interesting investment opportunity for the private entities involved. They were able to cover a large part of this area very quickly and with very little burden on the state budget.

This model therefore helps to minimise risks and costs for citizens and local authorities, whilst also maintaining a strong local presence and encouraging private-sector involvement in cases where public intervention is not strictly necessary. The total cost of the project is €150 million from private sources and just €6.56 million from the state budget, which was mainly directed towards upgrading the existing network. According to interim reports, by choosing this model, the state has managed to save approximately €100 million whilst also generating a positive impact through the creation of jobs within the project.

Digital Nord-Pas-de-Calais [25]

This project focuses on improving network infrastructure and connecting households, farms and businesses in areas with poor network coverage. A network totalling 20,000 km in length was built in just five years, and the project was awarded the 2022 European Broadband Award. Following the completion of the project, the current coverage of the region with high-speed broadband stands at 96.45 per cent. Thanks to the project, 50 per cent of households across the entire region have switched to the new fibre-optic network. This rapid roll-out across a relatively large area sets a good example for future network expansion, not only in France. The total cost of the project is around EUR 950 million.[26]

Following the completion of the project, a survey was conducted among local businesses to assess the impact of the new, modern network on the region. The majority of respondents agreed that high-speed internet had made remote working and communication more efficient, whilst also increasing the region's attractiveness to new employees from previously poorly covered, remote areas. Connecting local farms and weather stations via high-speed internet is also helping to reduce energy and water consumption in the area, thereby contributing to environmental sustainability.

3.1.3 Ireland

VHCN coverage reached 87 per cent of all households in 2023. The plan to modernise household coverage was delayed due to the COVID-19 pandemic, but it is expected that the original target of 100 per cent household coverage with a gigabit network will be achieved by 2028. Although the country's technological infrastructure is of a good standard, demand for high-speed services remains relatively low. The number of internet subscriptions with a download speed of at least 1 Gbit/s is only 9.8

% [27].

The Odyssey Network Expansion Project[28]

The main objective of this project is to design and roll out high-speed broadband connectivity (via FTTH) across Ireland to approximately 320,000 addresses. The project is expected to run until 2025, and the total estimated cost is €342 million. With the support of the European Investment Bank and a number of investors from Ireland and abroad, €620 million has been secured for this project, which will be used not only to roll out the network to new areas but also to upgrade it to a capacity of 2 Gigabits, doubling the speed of the current infrastructure.

The project is in line with the objectives of the 2025 Gigabit Society to improve internet coverage in remote areas, which will make a significant contribution to the future development of these areas.

The project is led by SIRO Limited, which focuses on expanding fibre-optic coverage across Ireland. Throughout the project, SIRO is working closely with public authorities to ensure the smooth roll-out of the network.

[25] https://digital-strategy.ec.europa.eu/en/library/digital-nord-pas-de-calais-france

[26] https://www.ijglobal.com/Widget/SaveAsPDF/105154

[27] https://ec.europa.eu/newsroom/dae/redirection/document/106713

[28] https://www.eib.org/en/projects/all/20210132

3.1.4 Liechtenstein

FTTB roll-out for all, Liechtenstein[29]

A 2017 project aiming for 100% VHCN (1 Gbit/s+) coverage across the whole of Liechtenstein by 2022. The existing cable (DOCSIS, CATV…) infrastructure was insufficient for these connection speeds; the project therefore involves a complete modernisation of the network to FTTB and the roll-out of the network to areas where high-quality broadband internet was previously unavailable. The phasing out of older technology and its replacement with FTTB is taking place in parallel; once FTTB has been rolled out to a property, a 12–18-month period begins, after which coverage at that address must be provided entirely by the new fibre-optic network. The target for the transition to fibre-optic internet services was therefore the end of 2023, one year after the planned nationwide coverage.

The project, led by the state-owned company Liechtensteinische Kraftwerke (LKW), covers 11 municipalities (39,000 inhabitants) across an area of 160 km^2, two-thirds of which consists of mountainous and less accessible regions. The network that has been built is available to all operators, and competition has thus had a positive impact on the prices of services offered to end customers and businesses. Liechtenstein is unique in that functional vertical separation via a passive open-access network – Passive OAN – has created a highly competitive market, with more than 10 operators per 40,000 inhabitants.

The latest available information (December 2023) shows that fibre-optic coverage in Liechtenstein now stands at 99 per cent, with only a fraction of the total number of addresses still awaiting network modernisation. The final migration of the remaining addresses to fibre-optic connections was scheduled to take place during the first half of 2024[30] .

3.1.5 Latvia

The 2022 DESI ranking reported VHCN coverage of 92 per cent of households, but a review of data collection during 2023 revealed that actual VHCN coverage in 2022 was only 62.7 per cent, placing Latvia below the European average. The proportion of internet subscriptions with a download speed of at least 1 Gbit/s is just 4.55 per cent, which is also well below the EU average (18.52 per cent)[31] .

3.1.6 Malta

Across the whole of the EU, Malta is the only country to report 100 per cent VHCN coverage, with FTTP coverage standing at 69.6 per cent. Part of the VHCN coverage is therefore provided by older technologies (DOCSIS, hybrid fibre-copper), which currently meet the requirements for a high-speed network; however, there are plans to modernise this infrastructure to 100% fibre in the future[32] .

GO True Fibre[33]

A project by the operator GO focusing on the modernisation of fixed internet networks, with a planned transition to full fibre-optic network coverage by the end of 2024. The project, which began in 2016 and has seen total investment of approximately 100 million euros over its eight-year duration, is well on track to achieve its objectives, with more than 267,000 households already covered (equivalent to approximately 80 per cent of the entire island)[34] .

3.2 Investment models

The choice of investment model for the roll-out of high-speed broadband is influenced by many factors. The investor must take into account the costs of network roll-out and the overall return on these investments, which is also linked to

[29] https://digital-strategy.ec.europa.eu/en/library/fttb-build-everyone-liechtenstein

[30] https://www.llv.li/en/national-administration/office-for-communications/electronic-communication/broadband-ftth-fibre-optic-expansion

[31] https://ec.europa.eu/newsroom/dae/redirection/document/106714

[32] https://ec.europa.eu/newsroom/dae/redirection/document/106707

[33] https://www.go.com.mt/news/fibre-is-forever/

[34] https://timesofmalta.com/article/2024-see-completion-go-true-fibre-project.1080333

demand for the services to be offered. The main criterion for classifying investment models is also the degree of involvement of public authorities, private entities and citizens themselves in individual areas.

We identify four main investment models:[35]

1. Direct investment model
2. Concession model
3. Community support model
4. Operator subsidy model

Direct investment model

In this model, the main entity is a public authority, which manages the design, construction and operation of the broadband network in the area concerned. In this case, the public authority remains the owner of the network, which it makes available to all market participants once construction is complete. The advantage of this model is that the public authority retains full control over the construction and maintenance of the network; however, it also entails significant financial costs for that authority.

Concession model

Unlike the previous model, this one offers the possibility of shifting the costs of network construction and maintenance from the public authority to a private entity. Under a long-term contract (usually spanning several decades) with the public authority, this entity builds and operates the network, thereby reaping all the revenues but also bearing the risks associated with network operation. The main advantage for the public authority is that it retains ownership of the network, which enables it, for example, to influence the operation of the network in accordance with regulatory decisions or the state's strategic plan for the provision of network services.

Community-led model

Unlike the previous models, in this case the construction and operation of the network are driven from the bottom up, based on the initiative of local residents (the community). This model has proved successful in many cases, particularly in terms of demand for services, which is very high in this instance precisely because the initiative comes from the end-users of the network themselves. In this case, the public authority may act in support of the community, both financially (in the form of co-funding), in terms of coordination (by ensuring the smooth integration of infrastructure from other networks and connection to the backbone network), and in a regulatory capacity (by overseeing fair conditions of access to the network for individual operators).

Operator subsidy model

This model is based on support provided by a public authority to the existing private network operator. Through financial support, the private operator is assisted in modernising and improving the current state of the network. Thanks to this funding, the private operator is obliged to bridge the gap between the current and optimal state of the network in accordance with the public authority's requirements. This investment model offers a relatively rapid way of achieving these requirements and objectives; however, it also represents a considerable financial investment, as all financial returns from operating the network remain with the network owner, who is usually the private operator.

3.2.1 The Netherlands

The Netherlands has VHCN coverage of 98.3% and FTTP coverage of 77.7% of households, placing the country above the EU average and bringing it close to the DDPP targets. Although coverage in the Netherlands is at a very good level, the number of subscriptions to high-speed services stands at a low 4.1%. Across the country, there are still approximately 19,000 households where fixed broadband with a speed of at least 100 Mbit/s is not yet available. The government estimates the cost of providing coverage to these remaining addresses at 195 million euros. The government plans to engage private market operators to ensure coverage

[35] https://digital-strategy.ec.europa.eu/en/policies/broadband-investment-models

with incentives for roll-out on favourable terms (state aid), thereby sharing the substantial financial costs of network roll-out[36] .

Of particular interest is an offer from one of the operators for high-speed 8 Gbit/s internet; however, this is not particularly attractive to ordinary customers. Businesses and companies will find uses for such a high-quality connection, for example, with the future roll-out of Industry 4.0 technologies (IoT, Big Data, etc.). The Netherlands' high-quality infrastructure is therefore far from being utilised to its full potential. One of the issues contributing to the low uptake of high-speed services is the relatively sharp rise in average tariff prices compared with other EU countries. In 2023, the two largest operators, KPN and Glaspoort, committed to reducing these tariff prices by 2030 in order to boost demand for high-speed internet[37] .

3.2.2 Portugal

With VHCN household coverage of 94.2% and FTTP coverage of 92.3%, Portugal ranks well above the EU average. At the same time, 89.7% of fixed internet subscriptions in Portugal are for speeds of at least 100 Mbit/s, which indicates a relatively high level of interest in high-quality, high-speed internet services. As regards plans to achieve 100% VHCN coverage, Portugal has not presented any comprehensive plan; however, given the current pace of network development, it can be estimated that, if this pace is maintained, these targets will be met in line with the DDPP by 2030.

At the end of 2023, Portugal launched a public tender for the roll-out, management and operation of a high-speed network offering speeds of at least 1 Gbit/s in selected areas. This plan covers approximately 417,000 addresses, and the expected costs are around 340 million euros. Almost half of this amount has already been approved in accordance with EU state aid rules. Coverage of all selected addresses is planned within a three-year timeframe[38] .

3.2.3 Romania

VHCN coverage in Romania stands at the same level as FTTP, namely 95 per cent of households. This figure places the country among the frontrunners within the EU. Romania has seen the greatest increase in coverage over the last five years; however, with the remaining 5 per cent of coverage, the pace is now slowing, and it is precisely this final stage that will prove the most challenging.

An interesting aspect in Romania is the number of high-speed internet subscriptions with speeds of at least 100 Mbit/s, which is set to reach 94 per cent in 2023, placing Romania in first place in the EU. As regards fixed-line subscriptions with speeds of at least 1 Gbit/s, the country ranks third in the EU. These excellent results are mainly due to high-quality coverage, but also to subscription prices, which are relatively low compared with the EU average. Thanks to a dynamic market and relatively high demand for high-speed internet, one of the operators has launched packages offering speeds of 2.1 Gbit/s.

The plan to cover the remaining areas is supported by a budget of 94 million euros from the Recovery and Resilience Plan (RRP). The Romanian telecommunications regulator, ANCOM, has identified the areas that are the primary focus of future network expansion and, in April 2024, issued a call for proposals from private entities for the construction of a state-supported network[39] .

The RO-NET project[40]

The main objective of this 2019 project was to extend fixed high-speed internet to areas not yet covered and outside the infrastructure expansion plans of private operators. Whilst broadband services are widely available in densely populated parts of Romania, the low population density in rural areas

[36] https://ec.europa.eu/newsroom/dae/redirection/document/106699

[37] https://www.acm.nl/en/publications/acm-rapid-rollout-fiber-optic-networks-which-various-internet-providers-are-admitted-will-lead-sufficient-competition

[38] https://ec.europa.eu/newsroom/dae/redirection/document/106698

[39] https://ec.europa.eu/newsroom/dae/redirection/document/106692

[40] https://ec.europa.eu/regional_policy/en/projects/romania/rural-areas-of-romania-get-broadband-coverage

makes it difficult to attract investment in the necessary infrastructure. The RO-NET project therefore set out to bridge these gaps, thereby improving conditions for businesses and companies in rural areas and making these areas more attractive to residents.

The project provided connections with speeds of at least 30 Mbit/s in the areas covered, 99 per cent of which are delivered via fibre-optic cable. The scope of the project covered approximately 200,000 households and over 8,000 public institutions and private businesses, served by 4,843 km of fibre-optic cable.

The total investment in the RO-NET project was €66,717,938, with the European Regional Development Fund contributing €45,779,730 through the 'Competitiveness' operational programme for the 2014–2020 programming period.

3.2.4 Spain

Spain significantly raises the EU average with the quality of its broadband networks, as UHFN coverage reached 96.3 per cent of households in 2023. Given the EU's targets for 100 per cent UHFN coverage by 2030, Spain is well on track to meet these targets ahead of schedule[41] .

The Aller Valley[42]

The initiative aims to prevent population out-migration from the Aller Valley region due to the decline of the local mining industry. The authorities in Asturias, where this valley is located, drew up a plan to roll out a high-speed FTTH network for local residents. The aim of this project was to provide 4,000 households with fixed broadband at speeds of at least 100 Mbit/s. The public lighting infrastructure was utilised for the roll-out, which significantly helped to reduce the overall cost of the project. Part of the new network is state-owned as part of a publicly accessible network, but the 'last mile' was provided and built by the operators themselves, who deployed the network in accordance with residents' requirements. Part of the project was funded by the Asturian authorities (40 per cent), whilst the majority was supported by EU grants (60 per cent).

NAVARA Broadband Plan 2016–2021[43]

This project, which follows on from the Digital Agenda for Navarre 2013–2016, addresses – just like its predecessor – the issue of the digitisation and transformation of the region's infrastructure, with a strong emphasis on the availability of broadband connectivity, in line with the EU's Digital Agenda for Europe 2020.

The main objective of this project was the digitisation of public services and the roll-out of broadband services to remote areas as part of a strategy to implement new technologies in rural areas. The project also aimed to create a digital society through the provision of accessible, high-quality technologies regardless of location, which will help to reduce the exodus of residents from these remote areas.

The uniqueness of this project lies in its complexity due to the uneven distribution of the population across the region (665,000 inhabitants), as only 9 of the total 883 municipalities have more than 3,000 inhabitants. The project was implemented through collaboration between public and private sector entities in the construction of a new network. Over a period of five years, 2,000 km of fibre-optic cable was successfully laid. At the business level, 82.6 per cent of local companies were connected to high-speed broadband, thereby enhancing the competitiveness and connectivity of the entire region[44] .

In 2021, this plan was followed by the ongoing 'II Broadband Master Plan 2021–2024' project, which aims to ensure access to broadband internet for all residents of the area, with speeds of at least 30 Mbit/s for villages with between 200 and 1,000 inhabitants and speeds of at least 100 Mbit/s for villages with over 1,000 inhabitants.

UNICO Broadband Programme [45]

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[41] https://ec.europa.eu/newsroom/dae/redirection/document/106695

[42] https://www.youtube.com/watch?v=n0DwRocfC-4

[43] https://gcpublica.navarra.es/publica01/EDN2030/Documents/EDN2030_en.pdf

[44] https://www.nasertic.es/es/actualidad/el-i-plan-director-de-banda-ancha-de-navarra-finalista-en-los-european-broadband-awards

[45] https://espanadigital.gob.es/en/measure/unico-broadband

This is a project under the auspices of the national telecommunications authority, launched in 2023. The long-term strategy is to ensure 100% coverage by a high-speed broadband network in Spain.

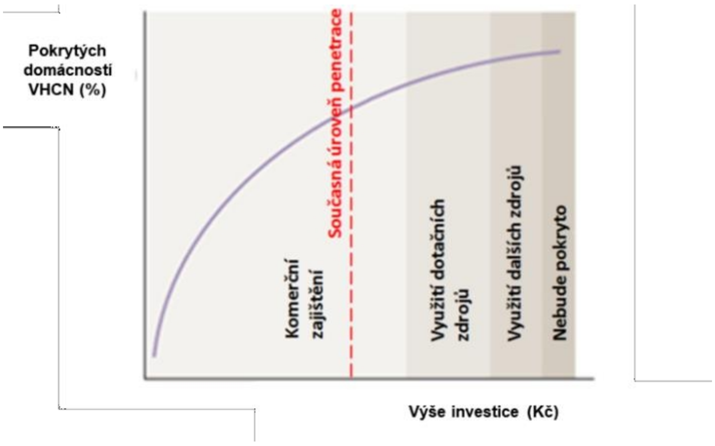
In 2023, the project was allocated a budget of €134.36 million, with the primary aim of connecting nearly 360,000 addresses to networks with download speeds of at least 300 Gbit/s (scalable to 1 Gbit/s), primarily in remote rural areas not included in earlier network expansion plans. A further objective is to develop and implement a sustainable growth model in line with the goals of the gigabit society.

3.3 The investment model as a tool for achieving the goals of the Digital Decade

It is not the aim of this study to set out a step-by-step guide to investment approaches; however, it is necessary to outline the key issues and summarise the fundamental recommendations. Given the ambitious targets of the European Union and the Digital Decade policy, which aim to connect all households in the Czech Republic using VHCN technology, there are relatively significant gaps in achieving this level of coverage.

In terms of the level of investment in available connections, it is clear that providers will invest where there is a high economic return on deployment, taking into account potential expected demand. A simple diagram illustrating the relationship between the level of investment in available connections and the rate of high-speed internet coverage is shown in Figure 1. This relationship can be expressed by a logarithmic curve, where a high level of investment can be reduced through subsidies or other sources (e.g. funding from the local authority budget or other sources).

Figure 1 Illustrative diagram of the relationship between coverage rate and investment level



In the context of VHCN network development and the fulfilment of connectivity targets set at both national and European levels (DESI), it is essential to update investment approaches. This applies in particular in connection with the dynamic development and expansion of 5G networks. The Czech Republic has a long tradition of deploying FWA technologies, which encompass both RLAN radio systems and new 5G networks. At present, FWA is regarded as a suitable solution for connecting rural areas where it is economically unviable to build fibre-optic infrastructure. This model has proved particularly advantageous in sparsely populated areas, where the roll-out of a fibre-optic network does not yield a return on investment, even in the long term.

Although FWA represents an effective solution for rural and sparsely populated areas, it is essential to prioritise the roll-out of as high a proportion as possible of fibre-optic networks, which offer significant technological advantages. Fibre-optic networks (FTTx) provide the highest data transmission speeds and ensure the sustainability of digital infrastructure for future generations of technology. The long-term benefits of fibre-optic networks include stable connectivity, low operating costs and minimal restrictions on data flow processing; at the same time, the conclusion of the aforementioned study clearly shows that *in smaller areas with higher* *population density – and therefore with a demand for higher radio channel capacity – designing an efficient network configuration will be difficult or even impossible*[46] .

Organic investment from private investors will not cover a sufficient number of households to meet the targets set out in the digital strategies of the Czech Republic or the European Union. Without state intervention or other support mechanisms, many localities, particularly in remote areas, will remain unconnected to VHCN networks. Grants and financial support, whether from national or European sources, provide some assistance, but are insufficient to attract private investors to less economically attractive areas. It is therefore necessary to reassess the existing subsidy models so that they are more targeted and focused on specific problems and on supporting the access network, not only in remote areas but also in areas with insufficient fibre-optic coverage.

Given the gap between the current and target levels of household coverage, there is essentially no investment approach that would guarantee the achievement of these targets. Therefore, in order to even consider achieving them, comprehensive and timely implementation of measures leading to increased household connectivity is required; this includes, for example, the following steps:

- **A combination of investment models:** The operator subsidy model and the concession model appear to be the most suitable. The subsidy model makes it possible to support existing private network operators who already have the infrastructure and operational experience. This reduces the costs of building new networks, as operators focus on modernising and expanding existing networks. In France, for example, the operator subsidy model has contributed significantly to providing coverage in rural areas where private investors lacked sufficient incentive to invest. The concession model, on the other hand, is better suited to areas where new infrastructure needs to be built from scratch, but where the public sector is unable or unwilling to bear the full financial burden. Municipalities and towns can thus, on the one hand, make use of unspent funds – given that the balance of unused funds in municipal accounts across the Czech Republic is currently significantly positive and is being eroded by inflation – whilst, at the same time, retaining control over access to the infrastructure and ensuring that the network is used in line with long-term national objectives. The concession model is, for example, successfully used in Denmark, where private operators participate in the construction of infrastructure with state support.
- **A more prominent role for local authorities**: To increase the incentive to build access networks, it is essential to focus on cooperation with local authorities. Local authorities should play an active role in providing incentives for infrastructure development and make use of funding opportunities from both state and European funds. Particular emphasis should be placed on maximising opportunities to lay fibre-optic ducts as part of road reconstruction and other public works projects.
- **Maximising opportunities for co-installation**: It is recommended to take every opportunity to lay conduits or fibre-optic cables during ongoing construction works. This may include a requirement to co-install conduits when carrying out the reconstruction or construction of linear infrastructure (electricity, water, road resurfacing, etc.[47]) In this way, construction costs can be significantly reduced and coverage increased, even in areas where a standalone investment in optical infrastructure would not be cost-effective.
- **Support and simplification of organisational and technical processes**: A key step towards accelerating network roll-out, particularly for FWA and 5G, is to reduce administrative and organisational-technical barriers. It is essential to significantly simplify authorisation processes, such as planning permission and approval procedures, which often prolong construction times and increase construction costs. In the context of 5G network development and the increasing efficiency of FWA technologies, simplifying legislative requirements would lead to faster coverage of less accessible locations. Inspiration could be drawn from the Danish approach to administrative barriers, which focuses on simplifying authorisation processes. This could contribute significantly to accelerating network roll-out and reducing the costs associated with bureaucracy.
- **Flexibility of support**: At the same time, it is necessary to reassess support not only for backbone and backhaul networks, but also for access networks in areas that have historically not been included in support programmes. Current analysis shows that areas with lower population density require not only financial support, but also technical assistance for the effective roll-out of infrastructure. Conversely, a combination of organisational and technical support – whether within municipalities and towns through the waiver of easement charges and an active role in project coordination – is an appropriate form of support.

  Notwithstanding the above, customer demand is the key driver of the development of connection speeds and quality. However, influencing customer demand is an area in which it is difficult to intervene, and such intervention is not even

[46] See footnote 12

[47] except for gas pipelines, where the issue of easements is more complicated.

is not desirable. It can be expected that, with the increase in data consumption, the development of the IoT and the rising quality and volume of audiovisual content, demand for higher-quality connections will also grow. However, at present, it cannot be expected that this demand will lead to such a significant increase in interest in VHCN connections as to ensure that the Czech Republic's connectivity targets are met.

Ensuring connectivity for households in the Czech Republic via VHCN networks requires a combination of technological solutions. FWA, thanks to its effectiveness in remote areas and its widespread deployment in the Czech Republic, should remain a key tool for connecting rural regions. At the same time, however, it is necessary to continue actively investing in fibre-optic networks, which offer the best technical characteristics. Any update to the investment gap calculation must take into account both rising construction costs and the need for public intervention in areas where private investors lack sufficient economic incentives to build.

4 Coverage scenarios

Across the Czech Republic, as of the 2021 census, there were more than 6,200 municipalities, which are further subdivided into approximately 15,000 municipal districts and more than 23,500 statistical localities; furthermore, according to data provided by the Ministry of Industry and Trade, as of 2024 there were almost 2.4 million residential units in the Czech Republic, which, together with flats, make up 5.1 million households. In the practical part of the project, we will focus on identifying the investment gap for individual households. The first step in the analysis is therefore to identify and define areas that are not connected to the VHCN infrastructure at all. This definition process was based on the identification of key parameters influencing, in particular, the current coverage rate and demographic factors (such as population density) within individual areas. As the data used in the public consultation on programmes to support high-speed internet coverage in the Czech Republic is based on information from 2019, this study will update the coverage map in line with the results of the latest available mapping of electronic communications network coverage as at 31 December 2023.

As part of this study, we do not intend to propose a single specific option, but rather to present a set of options that are in line with national targets (connecting 95–100 per cent of households to VHCN networks) and which provide regulatory and other competent authorities with sufficient room for manoeuvre whilst contributing to market efficiency. Of the total 23,587 service areas analysed, operators recorded no VHCN connections in 14,596 of them, and out of 5.1 million households, VHCN connections are recorded for 2.6 million. It is also important to distinguish between the costs associated with backhaul network roll-out and those associated with household coverage, and the fulfilment of the Digital Decade targets.

4.1 Scenarios for coverage of areas using fibre-optic and FWA technology

When setting out scenarios for calculating the investment gap in household connectivity according to DESI parameters, we based our approach on two assumptions. The first is the target pan-European DESI value for connectivity, namely 100 per cent coverage of households with VHCN technology by 2030, and the second is the adjusted target for the Czech Republic, which is 95 per cent of households connected via VHCN technology by 2030. In line with the VHCN categories, we then divided the scenarios into those where all households are connected via fibre-to-the-premises (FTTP) and those where this is combined with FWA technology; we further subdivided the scenarios based on the costs of FWA technology. Given the current household coverage in the Czech Republic, we also added a scenario with 90 per cent FTTx coverage to the coverage options.

Table 2 – Overview of scenarios

Scenarios	Description
Scenario 1: 100% FTTx coverage	The first scenario describes a situation in which all households will be covered by a fibre-optic connection. This therefore includes both the completion of the backhaul network to all local exchange areas and the roll-out of the FTTP (FTTH-FTTB) access network.
Scenario 2: 95% FTTx coverage	The second scenario describes a situation where 'only' 95 per cent of households will be covered by fibre-optic connections. Here, we envisage the completion of the access network and backhaul connections to all local service areas and households where this option is more cost-effective (lower costs).
Scenario 3. 90% FTTx Coverage	The third scenario is essentially identical to Scenario 2, with the difference that the target coverage rate is 90 % of households. Here too, we are considering the completion of the access network and backhaul connections to all residential areas and households where this option is more cost-effective (lower costs).
Scenario 4. Combination of FTTx & FWA – 95% coverage for ZSJ with 16 households	The fourth scenario envisages connecting 95 per cent of households using VHCN technology; however, here we envisage a combination of FTTP connections for households (VHCN Category 1) and ZSJ areas where the population density is very low, comprising 16 households in the service area. Households with the highest backhaul and access network construction costs will be connected using FWA technology. This scenario takes into account the construction costs and the range limitations of FWA technology per radio unit, which is capable of connecting approximately 16 households within the transmitter's range; however, it does not consider the technical feasibility of BTS construction (BTS capacity , and the legislative options for constructing new BTSs).

Scenario 5. Combination of FTTx & FWA: 95% coverage for a small settlement with 32 households	The fifth scenario envisages connecting 95 per cent of households using VHCN technology; as in Scenario 4, we envisage a combination of FTTP connections (VHCN Category 1) and small settlements where the population density is low, with up to 32 households per settlement. For households with the highest roll-out costs, the backhaul and access networks will be connected using FWA technology. This scenario takes into account the roll-out costs and the range limitation of FWA technology to two radio units, which is capable of connecting approximately 32 households within the transmitter's range; however, it does not consider the technical feasibility of BTS construction (BTS capacity of BTSs, and the legislative options for constructing new BTSs).

Scenario 6. Combination of FTTx & FWA: 95% coverage for a ZSJ with 48 households	The sixth scenario envisages connecting 95 per cent of households using VHCN technology; like Scenario 4, it envisages a combination of FTTP connections for households (VHCN Category 1) and ZSJ connections in areas with very low population density, comprising 48 households in the service area. Households with the highest backhaul and access network construction costs will be connected using FWA technology. This scenario takes into account construction costs and the range limitations of FWA technology to three radio units, which are capable of connecting approximately 48 households within the transmitter's range; however, it does not consider the technical feasibility of BTS construction (BTS capacity, legislative options for the construction of new BTSs).
Scenario 7. Combination of FTTx & FWA: 95% coverage for a ZSJ with 64 households	The seventh scenario envisages connecting 95 per cent of households using VHCN technology; like Scenario 4, it envisages a combination of FTTP connections (VHCN Category 1) and small settlements, where there are up to 64 households in the settlement. Households with the highest backhaul and access network construction costs will be connected using FWA technology. This scenario takes into account construction costs and the range limitations of FWA technology to four radio units, which are capable of connecting approximately 64 households within the transmitter's range; however, it does not consider the technical feasibility of BTS construction (BTS capacity of BTSs, and the legislative options for constructing new BTSs).

4.2 Definition of parameters

Our analysis is based on data provided by the Ministry of Industry and Trade (MPO) and freely accessible data from the Czech Statistical Office (ČSÚ). The MPO data focus on speed and coverage of individual statistical areas, whilst the ČSÚ data focus on demographic characteristics (GPS, area, etc.) of these areas. For each parameter of the scenarios, it is also necessary to define how the parameters were sorted and calculated. In this regard, we draw on data from the Czech Statistical Office and its current public datasets.

Distance to the nearest PoP

- This is a metric that links the coordinates of the nearest PoP to the centre of gravity of the ZSJ.

Population density:

- The variable represents the number of OBAMs in a given ZSJ divided by the total area of the ZSJ. This metric is used to determine more accurately the costs associated with the construction of an access network (investment in available connections) for all OBAMs, or flats within a given OBAM.[48] Population density is further converted to a three-point scale reflecting the nature of the settlement:
  - Dense settlement (metropolises, towns and dense built-up areas): these are ZSJs with more than 200 OBAMs per 1 km². [49]
  - Medium-density settlement: (Smaller towns and villages); these are settlement units with more than 50 and fewer than 199 OBAMs per 1 km² .
  - Sparse settlement: (Smaller villages, isolated settlements), this refers to settlement areas with fewer than 50 OBAM per 1 km² .

FWA coverage

When simulating and modelling FWA connections, we base our calculations on the 'Assessment of the possibilities for deploying WAS/RLAN technology in the 5 470 to 5 725 MHz frequency band for network implementation'; for connections with VHCN parameters, we assume a channel bandwidth of 80 MHz. Together with the interference parameter, FWA coverage is only considered in areas with a population density of less than 20 dwellings per km² .[50] For 5G FWA, we assume a 1- to 4-sector transmitter using 256 QAM LTE modulation and an 8×8 MIMO configuration, and subsequently calculate the connection capacity of the connections using the calculator for assessing the impact on network capacity provided by the Czech Telecommunications Office (ČTÚ)[51] . As a rough generalisation, this corresponds to approximately 16 connectable households per sector.

[48] However, this is merely an illustrative calculation – the level of investment required for an available connection always depends on local conditions.
[49] When converting to a per capita basis, we use data from the Czech Statistical Office (ČSU), according to which the average household, as per the 2021 census, comprises 2.15 people.
[50]https://www.verejnakonzultace.cz/ARCHIV/Dokumenty/Posouzeni%20moznosti%20WiFi%20v%205%20GHz%20FIN%2021_11_2019.pdf

[51] https://ctu.gov.cz/vyhodnocovani-kapacity-siti

Network backhaul technology costs:

- **FTTx –** costs depend significantly on the location and length of the trench. The total cost of trenching will be calculated as 1 km of fibre for the given area, according to the category and population density. To determine the price, we drew on discussions with industry stakeholders and expert analysis, whereby the total costs of fibre-optic deployment include not only actual costs but also administrative costs. The costs are illustrated in the table below[52] .

Type of settlement	Costs of the access network (CZK/km)
Densely populated areas	**1,500,000**
Medium-density settlement	**1,200,000**
Sparse population	**800,000**

- **FWA**: Calculated as the costs of base station equipment and associated support technologies (power redundancy, backup systems, spectrum costs), and the number of households that can be connected to a single FWA base station. The calculation of FWA costs is the same for all types of settlement where the population density is less than 20 households per km². The costs of constructing and operating a base station capable of guaranteeing VHCN parameters at a distance of 1–3 km were determined according to a specific scenario corresponding to the number of transmitters at the base station. At this point, it is important to note that there is a high degree of generalisation, both in terms of the number of connected households per sector and, in particular, in terms of construction costs. For the purposes of this study, we assume that FWA deployment will take place using both Wi-Fi in the unlicensed spectrum and 5G FWA; however, the cost differences between these two technologies are significant. Therefore, the construction cost stated here has been selected as a possible figure based on a combination of 5G FWA and Wi-Fi. An accurate estimate of the costs of constructing FWA networks for the Czech Republic would require a detailed study covering various settlement patterns and geographical topologies across the country.

Coverage scenario	Households connected via FWA in this scenario
S4-FWA capacity per flat on WAS/RLAN	**16**
S5-FWA capacity per flat on WAS/RLAN	**32**
S6-FWA capacity per flat on WAS/RLAN	**48**
S7-FWA capacity per apartment on WAS/RLAN	**64**

Coverage scenario	FWA construction costs (CZK)
S4-FWA capacity per flat on WAS/RLAN	**460,000**
S5-FWA capacity per flat on WAS/RLAN	**490,000**
S6-FWA capacity per flat on WAS/RLAN	**520,000**
S7-FWA capacity per flat on WAS/RLAN	**550,000**

[52] These are cost categories at the upper end of the cost spectrum.

Access network costs:

- Access network costs are based on an expert estimate of household connections (flats in OBAMs), where the specific connection cost is derived from the type of settlement (dense, sparse, etc.), which determines the average distance of access network cabling; this is then multiplied by the number of OBAMs. The cost is calculated as FTTP (a combination of FTTH and FTTB)

Type of settlement	Cable run distance (m)	Total access network costs (CZK)
Dense settlement	**20**	**15,000**
Moderately dense population	**35**	**25,000**
Sparse population	**90**	**60,000**

VHCN Coverage:

We base our findings on data collected as part of the 2023 survey of electronic communications network coverage; we consider VHCN to be those locations that are covered by FTTP & DOCSIS 3.1[53]technology, together with FWA (both fixed and mobile)**, and which simultaneously meet the VHCN criteria**.

4.3 Methodology for calculating the investment gap

The aim is to calculate the investment gap for connecting all ZSJ, OBAM and flats (households) in the Czech Republic via VHCN by 2030. The investment gap will be calculated according to defined scenarios as the costs associated with covering all households with VHCN networks (BEREC categories 1–4). The definition of the investment gap for local access networks without a backhaul connection is also part of the analysis; this comprises the costs of trenching and connecting optical cables (FTTN, FTTC, FTTH-GPON, etc.) and connecting all relevant households in the given local access network via the access network.

4.3.1 Calculation procedure

1. Filtering of service areas already connected to VHCN

Objective: To identify addressable locations that already have a connection to VHCN technologies.

- Step: Using a database tool and the dataset, service areas (ZSJ) and address points (OBAM) were filtered according to the data_art232 table. This table lists the number of all OBAMs where at least one operator has entered ‘vhcn network’ = 1. These locations were excluded from further calculations.

2. Backhaul network at ZSJ level

Objective: To identify ZSJs where no backhaul network has been deployed.

- Step: From the MPO’s backhaul data, those ZSJs with no recorded backhaul were filtered out [54].

- Using data on grants from the Broadband Competence Office (BCO), those ZSJs where the backhaul network is expected to be completed during 2025 were added and filtered.

[53] It should be noted that not all connections covered by DOCSIS 3.1 technology and, of course, FWA meet the VHCN parameters; for the purposes of the analysis, only those with a recorded VHCN connection were selected.
[54] The final data source for the ‘Backhaul’ parameter is information compiled by the Ministry of Transport and Communications (MPO) on the basis of public consultations held in the first half of 2024 prior to the announcement of the first call for proposals under the OP TAK. At the same time, those locations supported by the NPO with a planned project completion date of 2025 are counted as connected to the VHCN.

3. Distance to the nearest POP (Point of Presence)

Objective: To calculate the distance from the ZSJ to the nearest POP with a VHCN connection.

- Step: Using geolocation tools (QGIS), the distance of each unconnected ZSJ [55](GPS coordinates) to the nearest POP is calculated. The distance is calculated both as the straight-line distance (FWA) and the distance along routes (for fibre-optic trenching).

4. Simulation of VHCN coverage for 2025–2030

Objective: To prioritise coverage of households (OBAM/flats) based on distance to the POP and the population density of the ZSJ.

- Step 1 – First year: ZSJ areas with no recorded backhaul connection:
  In Year 1, we will connect the most suitable ZSJ areas, i.e. those with the lowest costs and which meet the other criteria (i.e. shortest distance to POP/population density).
  The new coverage calculated on the basis of these parameters determines how many locations can realistically be connected in a given year (using previous data on average annual connections).

- Step 2 – Updating distances:
  At the end of Year 1, we recalculate the distances of the remaining unconnected locations to the model's already connected POPs (including those from Year 0), as the newly connected locations may reduce the distance from the nearest POP to the given service area.
  This process is repeated every subsequent year over 6 iterations (2025–2030).

5. Calculation of backhaul and access network costs

Objective: To estimate the costs of connecting each ZSJ based on its distance to the POP and other parameters. Estimating access network connection costs (OBAM/dwelling to POP)

- Step 1: For each year of the simulation, the costs of connecting ZSJs are calculated based on their distance to the POP and the nature of the housing in the ZSJ.
- Model: A calculation model (linear regression) in which costs are derived from distance and other factors. Cost estimates for each year.
- Step 2: For each year of the simulation, the costs of connecting OBAM per dwelling are calculated based on population density and the costs associated with the access network for all households in the given ZSJ.
- Step 3: For all households not covered by VHCN, the access network costs are calculated in the same way as in Step 2.

6. Alternative technology (FWE-5G)

Objective: To optimise the costs of simulating alternative technologies

- Step 1: Filter out the most expensive network points with up to 20 flats (see calculation methodology: cost of fibre per km, distance to the nearest PoP)
- Step 2: Calculate the connection costs for the 5% most expensive FWA technology service areas.

7. Cost calculation

4.3.2 Restrictions and limitations of the calculation

It should be noted that this study is characterised by a number of generalisations[56] , and that, given the varying data sets and the temporal evolution of individual values, the model has a number of limitations. Limitations arising from data inconsistencies are caused primarily by the emergence of new service areas on the one hand and the discontinuation of service areas on the other (generally, there is a trend of a slight increase in the number of service areas over the years). In reality, it can be expected that the specific ZSJs to be connected will be based on the internal strategies of businesses operating in the electronic communications sector, and a detailed overview will, as is currently the case, be based on public consultations and the refinement of support locations.

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[55] Centre of meaning (60182/VYZNSTRED_COBCE) https://apl.czso.cz/irso4/home.jsp

[56] We comment on generalisations either within this chapter, above, or when analysing individual scenarios.

Source data: Forms completed as part of the mapping of electronic communications network coverage (Form Art 242) may contain incorrect or incomplete data, whereby businesses may incorrectly report the coverage category or technological coverage category of a given administrative municipality.

Model vs reality: Given the complexity of the issue as a whole and the large number of variables, modelling the investment gap and simulating connections is merely an illustrative calculation that does not reflect the specific conditions at a given location. The amount of investment required for an available connection always depends on local conditions.

Backhaul: According to data provided by operators and processed by BCO Czech Republic, only 1,255 ZSJs are listed as having no backhaul connection. For the analysis of backhaul network roll-out, a restriction was applied whereby the cost was calculated as roll-out only to these specific ZSJs. Given that, of the total 23,587 ZSJs, over 2,000, for example, comprise ZSJs with no registered dwellings, this figure increases the uncertainty regarding the data reported by operators.

Variable conversion ratios: Over the years, the number of basic settlement units (BSUs), the number of residential address points (RAPs) and the average number of inhabitants per household have all changed. For this reason, there may be minor differences in the data and results across the various sources used in this analysis. However, these differences are relatively small – they may amount to tens within a ZSJ, thousands within households, and tenths of a per cent for the number of inhabitants per household. This means that the resulting data cannot be compared on a 1:1 basis, as they may contain slight discrepancies that need to be taken into account.

Data cleaning: Those ZSJs where the number of unconnected OBAMs is less than 1 (i.e. decimal numbers or negative values) were excluded from the analysis. The main reasons for their occurrence are as follows:

- This is a discrepancy between databases arising from the merging or creation of new administrative units; consequently, the data for 2023 and 2024 may include administrative units where the number of flats has decreased, yet a higher number of connected OBAMs per flat is reported than the total number of OBAMs and flats.
- Similarly, in the case of subsidies, where the subsidies report a higher number of AMs (OBAMs per flat) than the actual number of OBAMs per flat in the relevant ZSJ.

Overall, these discrepancies relate to a few dozen ZSJs, which were therefore excluded from the analysis, and OBAM per flat in the relevant ZSJ are considered to be fully covered by VHCN networks.

Growth in the number of households: Given the purpose of this study, we have decided to disregard the rate of growth in the number of households and are basing our analysis on data from 2023. Demographic data clearly show that the number of households is increasing, or rather that the average number of people per household is decreasing; however, this figure has varied so significantly in recent years that, for the sake of clarity, we have decided not to include it in the model.

VHCN – DESI: There is a discrepancy between the data provided on VHCN household connections and that from the report *Digital Decade 2024: Broadband Coverage in Europe*[57] – compiled for the European Commission by Omdia and Point Topic – shows that, as of 2023, 55.8 per cent of households in the Czech Republic are connected via VHCN technology (50.5 per cent FTTx and 5.3 per cent FWA), whereas the analysed data reported by operators for 2023 show a connection rate of only 51 per cent. This discrepancy is due to differences in methodology; nevertheless, in terms of the definition of the investment gap, it represents a significant difference. **In this study, we therefore draw on the information in the dataset and estimate that 50.7 per cent of households are connected, i.e. 2,611,117 OBAM/flat.**

[57]https://digital-strategy.ec.europa.eu/en/library/digital-decade-2024-broadband-coverage-europe-2023

5 Results of the VHCN network construction cost analysis

In this chapter, we present the results of the analysis we carried out based on the seven scenarios outlined above. The analysis focused on identifying the investment gap required to achieve the connectivity targets set out under the Digital Decade (formerly DESI). These targets are based on the aim of ensuring VHCN connectivity for households across the Czech Republic. The key parameters influencing the size of the investment gap were the chosen technology and the proportion of households connected. The scenarios covered two main technological options for connectivity: FTTx optical technologies (specifically FTTP) and FWA. The level of investment in each scenario depended on the varying levels of household coverage provided by these technologies and on the capacity required to achieve an optimal level of connectivity in line with European standards. The aim of this analysis was to provide a basis for quantifying the necessary funding and to set priorities for future investment programmes in the roll-out of VHCN networks.

5.1 Estimation of the concentration curve and cost categories

In this section, we present the results of the investment gap analysis and the simulation of connections for unconnected local authority areas and households. First, we focus on quantifying the investment gap according to the scenarios outlined above, and subsequently on defining the investment gap for localities not covered by a backhaul connection. **The figures given in this chapter are merely illustrative calculations, as the level of investment required for an available connection and for connecting a specific household always depends on local conditions**.[58]

Earlier analyses of the status and development of high-speed networks assumed an annual growth rate of around 5 per cent for 1 Gbit connections (particularly FTTx) (2019, 2021[59])[60] . Data up to 2023 suggest that this coverage forecast was accurate, as the analysis predicted that 2.6 million dwellings would remain unconnected in 2023. In fact, 2,535,836 households were not connected to VHCN networks in 2023, representing almost 50 per cent of all households in the Czech Republic. Looking at the number of unconnected OBAMs, 1,881,475 were unconnected, i.e. 79 per cent. There were 2,404 ZSJs in which not a single VHCN connection was recorded. On the other hand, according to the analysed data, backhaul capacity was not recorded for only 1,255 (5.3 per cent) of the ZSJs, which together have 80,500 OBAMs/flats and account for just 1.56 per cent of the total number of households (see table below).

	Total	Available backhaul	Connected to VHCN	Not connected to VHCN
ZSJ	23,587	22,332	NA	NA
OBAM	2,386,409	NA	504,934	1,881,475
Flat	5,146,953	NA	2,611,117	2,535,836

5.1.1 Investment gap in household coverage

In line with strategic documents on the development of high-speed networks, we have proposed seven scenarios for the development of VHCN networks. The first three scenarios favour optical connection technology (FTTH/FTTB), which, compared to FWA, offers

[58] For the sake of clarity, some figures, particularly in the text, have been rounded

[60] https://www.mpo.gov.cz/assets/cz/e-komunikace-a-posta/elektronicke-komunikace/koncepce-a-strategie/narodni-plan-rozvoje-siti-nga/2020/2/Final-report_GTA_12_12_2019.pdf

https://www.mpo.gov.cz/assets/cz/e-komunikace-a-posta/elektronicke-komunikace/koncepce-a-strategie/narodni-plan-rozvoje-siti-nga/2021/3/149908-21_III_mat_VHCN.pdf

significant advantages, particularly in terms of the long-term sustainability of network capacity. With the exponential growth in data traffic, optical infrastructure is undoubtedly the most suitable choice from both a technological and operational perspective, as it ensures maximum transmission capacity, low latency and minimal bandwidth constraints. However, the roll-out of optical networks in rural and sparsely populated areas is often economically unviable. The return on investment in these areas, even assuming a 100 per cent subsidy for the construction of the physical infrastructure, still proves to be negative when operating costs are taken into account. In such cases, it is essential to consider alternative solutions.

The second possible technology, FWA – including the use of 5G, as modelled in scenarios 4 to 7 – has a strong tradition in the Czech Republic. At the same time, it is also regarded as an acceptable option in terms of performance and construction costs (connecting end-users) when building new networks. FWA offers flexibility, rapid deployment and adequate service quality, which is particularly suitable for areas where the construction of a fibre-optic network would be uneconomical. The parallel use of both technologies appears to be appropriate for achieving the national VHCN objectives. The combination of FWA and 5G will make it possible to overcome economic barriers whilst ensuring high-quality connectivity in areas where fibre-optic infrastructure is not viable.

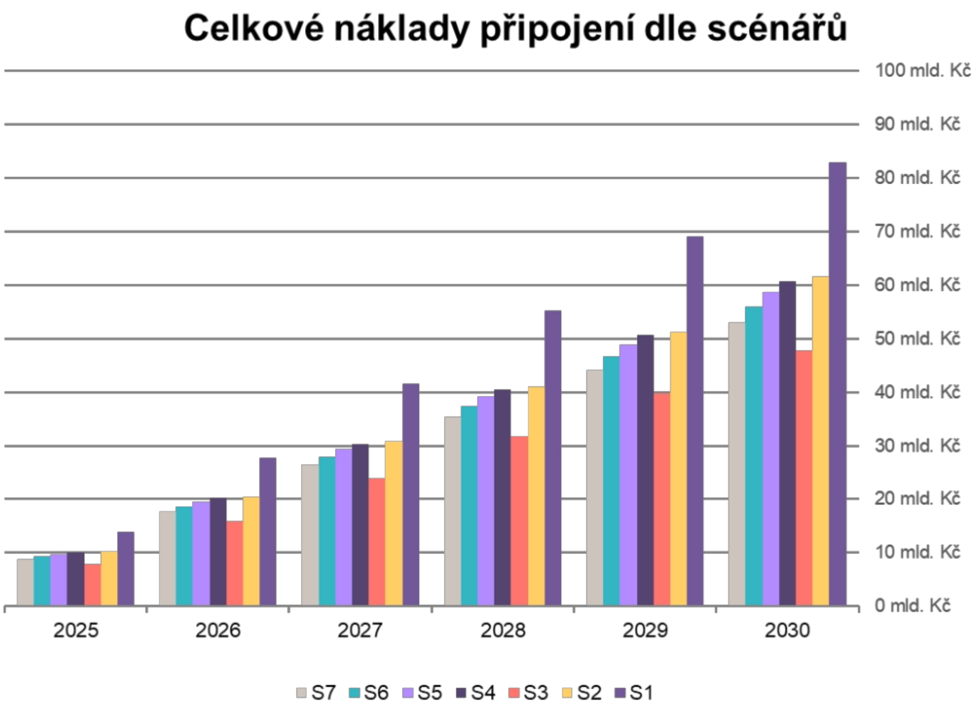
A number of scenarios were selected primarily due to the significant difference in connection costs. The data is based on the calculation method described in Chapter 4, which utilised data collected by the Czech Telecommunications Office (ČTÚ) from operators. The calculation procedure and limitations are outlined in the chapter above.

Looking at the summary table 3, it can be seen that the difference in total costs between the most expensive and cheapest options – with 100% coverage of all households by the fibre-optic network and 95% coverage in scenario 7 – is 45%. When comparing Scenarios 2 and 7, which meet the Czech Republic's KPIs for the Digital Decade, the cost difference is approximately 14 per cent; it is interesting to note that, despite the 55:45 split in the number of households by technology (between FWA and FTTx), the proportion of households covered by fibre is 89 per cent. Thus, slightly over 2 million of all uncovered households are covered by the fibre-optic option. The remaining approximately 246,000 households account for 45 per cent of the ZSJ not covered by fibre-optic networks, but only 11 per cent of all households.

Table 3: Summary of coverage investment gap scenarios

Scenario	Investment (CZK)	km of backhaul network	% of service areas covered by fibre	% of ZSJ areas covered by FWA	% of households covered by fibre	% of households covered by FWA
Scenario 1: 100% FTTx coverage	82,956,028,622	2,053	100%	0%	100%	0%
Scenario 2: 95% FTTx coverage	61,509,239,805	5	100%	0%	95%	0%
Scenario 3: 90% FTTx coverage	47,709,929,225	4	100%	0%	90%	0%
Scenario 4. Combination of FTTx & FWA 95% coverage for a residential block with 16 flats	60,716,085,000	0	89%	11%	99%	1%
Scenario 5. Combination of FTTx & FWA 95% coverage for a housing estate with 32 flats	58,704,650,000	0	73%	27%	96%	4%
Scenario 6. Combination of FTTx & FWA 95% coverage for a residential area with 48 flats	55,995,900,000	0	63%	37%	93%	7%
Scenario 7. Combination of FTTx & FWA 95% coverage for ZSJ with 64 flats	52,955,465,000	0	55%	45%	89%	11%

Chart 1: Total cumulative connection costs by scenario



5.1.1.1 Scenario 1: 100% FTTx coverage

The first scenario focuses on a situation where all households in the Czech Republic would be covered by fibre-optic infrastructure, specifically FTTP (FTTB-FTTH) technology. This scenario includes both the construction of a backhaul network and backhaul connections for all basic settlement units (ZSJ), as well as the roll-out of an access network for individual households. The scenario envisages the roll-out of a fibre-optic network right up to the final point of consumption, which represents a complex and financially demanding solution. According to our analysis, this scenario is the most expensive option among those considered, with estimated costs 37 to 47 per cent higher than alternatives involving a combination of technologies (e.g. S4 or S7, combining FWA and fibre-optic). Although 100% coverage by fibre-optic infrastructure would be ideal in terms of long-term capacity and technological sustainability, this objective is unachievable for the Czech Republic within the next few years and, from an economic perspective, would be ill-advised. This is primarily due to the high investment costs associated with building access and backhaul infrastructure, particularly in rural and sparsely populated areas, where the return on investment remains negative even when taking into account 100 per cent subsidies for the construction of physical network elements.

The analysis suggests that providers will invest primarily in areas where the cost per connection is lower and where high demand for high-speed internet is expected. The economics of such an investment are clear, with the relationship between the level of investment and the degree of coverage often expressed by a logarithmic curve, as shown in Section 3.3. High investment costs can be reduced through subsidies or other sources, such as funding from local authority budgets or operational programmes.

In the case of 100% coverage by fibre-optic infrastructure, the size of the investment gap increases significantly. Based on an analysis of the data, approximately 2.5 million dwellings were not covered by fibre-optic networks by the end of 2023, representing approximately 49% of all residential units. If we assume an annual increase in fibre-optic network coverage of 5 per cent, the number of available connections may rise within a few years; however, a significant proportion of dwellings will still remain without fibre-optic connectivity without support.

To provide fibre-optic infrastructure coverage for the remaining 2.5 million dwellings, the investment gap would amount to approximately 83 billion CZK. This figure includes the construction of the network itself, but does not take into account the associated operational and maintenance costs. The cost concentration curve thus shows that, using 33 per cent of dedicated costs (during the first two years of the simulation), 73 per cent of all households would be covered. The graph below illustrates the development of the concentration curve and the average cost of connecting a household; these data correlate strongly, with 22 per cent of all households being connected in the first year of the simulation households with an average connection cost of 12,000 CZK, whilst in the final year of the simulation only 2 per cent of households are connected and the average connection cost rises to 33,000 CZK. For more detailed information, see Table 4 and Figure 2.

It can be concluded that, although 100% coverage with fibre-optic technology represents the theoretically best solution in terms of future digital infrastructure, its implementation is financially demanding and, in many cases, impractical. Nevertheless, efforts should continue to achieve the highest possible coverage with fibre-optic networks, whilst at the same time considering realistic technological solutions, including the parallel deployment of hybrid FW models.

Figure 2: Concentration curve of total costs and the cost of connecting one household in Scenario 1

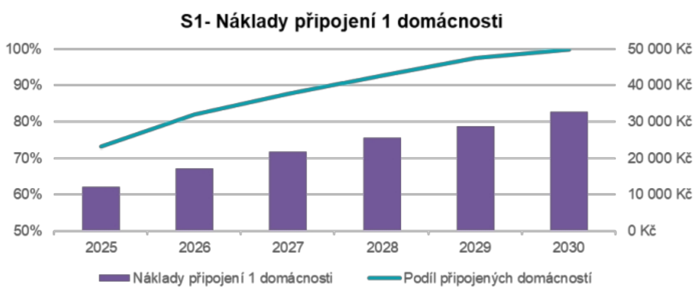


Table 4: Scenario 1: 100% FTTx coverage

Scenario 1: 100% FTTx	2024	2025	2026	2027	2028	2029	2030
Number of connected ZSJs in the given year		4,373	3,250	2,272	2,762	3,696	4,788
Total number of connected ZSJ		6,819	10,069	12,341	15,103	18,799	23,587
Number of households connected in the given year		1,144,603	463,228	289,358	266,127	246,978	125,525
Total number of connected households		1,144,603	1,607,831	1,897,189	2,163,315	2,410,293	2,535,818
Total number of connected households	2,611,117	3,755,720	4,218,948	4,508,306	4,774,432	5,021,410	5,146,935
% of households connected to VHCN	51%	73%	82%	88%	93%	98%	100%
km – fibre-optic		-	5	5	6	8	2,029
Average cost of connecting one household (CZK)		12,079	17,198	21,863	25,564	28,681	32,714
Connection costs for the year (CZK)	-	13,826,004 770	27,652,009 541	41,478,014 311	55,304,019 082	69,130,023 852	82,956,028 622

5.1.1.2 Scenario 2: 95% FTTx coverage

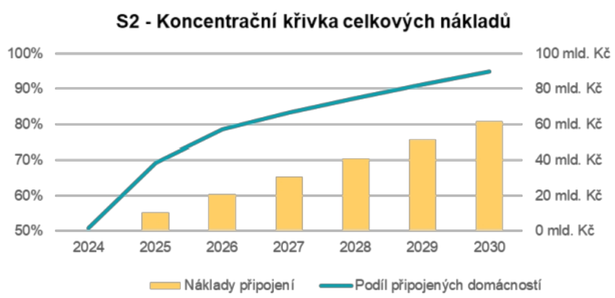
Scenario 2 focuses on providing FTTx coverage to 95% of households. This scenario is sufficient to meet the Czech Republic's KPIs, particularly in light of the EU's Digital Strategy (DDPP), which requires gigabit connectivity. Covering 95 per cent of households with fibre-optic networks will enable the full achievement of the Digital Decade's objectives, whilst ensuring sufficient connection quality and capacity for the majority of the population.

Achieving this level of coverage also represents a significant reduction in overall costs compared with full 100% coverage; the investment gap for connecting all remaining households (2.4 million) to the fibre-optic network would amount to approximately 62 billion CZK. The remaining 5 per cent of households are located in remote and sparsely populated areas, where infrastructure costs are very high. The fact that the 5 per cent of the most costly households will not be connected via fibre-optic infrastructure thus significantly reduces the costs of building the backhaul network; in this scenario, instead of 2,053 km of fibre-optic cable, only 5 km of access network remains to be built. The same applies to the cost of the access network; the total costs of this scenario are therefore 16 per cent lower than in Scenario One. Based on the investment gap calculations set out in the previous chapter and the data in the table and graph, we can see that the costs of achieving 95 per cent coverage are significantly lower than those for full coverage. The concentration curve suggests that a large proportion of the costs is associated with the final few per cent of households, which are the most difficult to reach.

The estimated average annual investment for connecting a single household is around 21,000 CZK. As in Scenario 1, there is a significant difference here between the costs of establishing a connection in the first and final years of the simulation; however, this difference is now 'only' around 16,000 CZK, which is over 4,000 CZK less than in Scenario 1. This amount includes the construction of the network itself, but does not take into account the associated operational and maintenance costs. The cost concentration curve thus shows that, using 33 per cent (the first two years of the simulation) of dedicated costs, 79 per cent of all households would be covered. The graph below shows the development of the concentration curve and the average cost of connecting a household: in the first year of the simulation, 18 per cent of unconnected households and 69 per cent of all households are connected, with an average connection cost of 11,000; conversely, in the final year of the simulation, only 4 per cent of households are connected, at a cost of around 27,000 CZK. For more detailed information, see Table 5 and Chart 3.

Covering 95 per cent of households with fibre-optic connections not only enables the fulfilment of national and European targets but also optimises investment gaps in geographically more complex areas. This approach makes it possible to achieve gigabit speeds and high connection reliability for the vast majority of the population, which is critical for long-term digital development. This scenario also allows for better distribution of access networks and minimisation of investment risks associated with the construction of new distribution points, whilst the costs of connecting the final 5 per cent of households can be implemented gradually, using modern technologies such as FWA/5G.

Figure 3: Concentration curve of total costs and the cost of connecting one household in Scenario 2



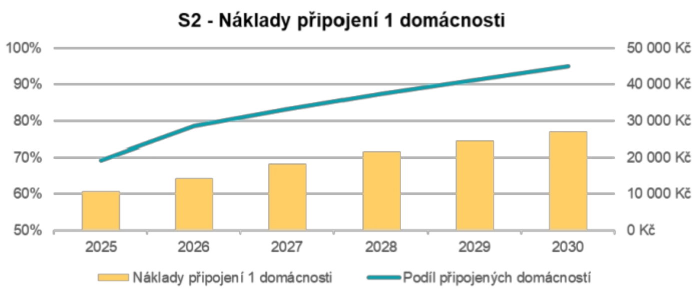


Table 5: Scenario 2. 95% FTTx coverage

Scenario 2: 95% FTTx	2024	2025	2026	2027	2028	2029	2030
Number of connected ZSJs in the given year		3,511	2,619	1,933	1,655	2,075	2,369

Total number of connected ZSJ		5,957	8,576	10,509	12,164	14,239	16,608
Number of households connected in the given year		949,983	481,380	244,174	212,084	199,769	189,527
Total number of connected households		949,983	1,431,363	1,675,537	1,887,621	2,087,390	2,276,916
Total number of connected households	2,611,117	3,561,100	4,042,480	4,286,654	4,498,738	4,698,507	4,888,033
% of households connected to VHCN	51%	69%	79%	83%	87%	91%	95%
km – fibre-optic		-	1	1	1	1	2
Average cost of connecting one household (CZK)		10,791	14,324	18,355	21,724	24,556	27,014
Connection costs for the year (CZK)	-	10,251,539 967	20,503,079 935	30,754,619 902	41,006,159 870	51,257,699 837	61,509,239 805

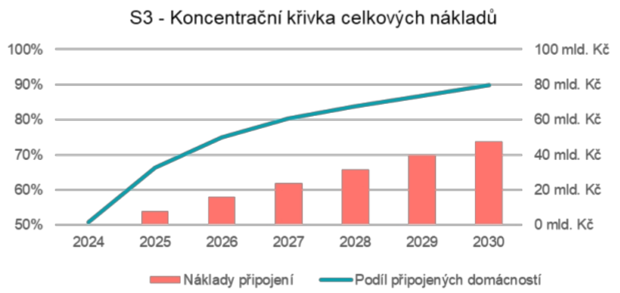
5.1.1.3 Scenario 3. 90% FTTx coverage

This scenario was chosen primarily to illustrate how significantly costs are reduced if a decision is taken not to build infrastructure in remote and sparsely populated areas. This is an illustrative calculation which clearly shows that, by achieving 90% FTTx coverage, a high level of coverage can be attained at substantially lower investment costs. However, this scenario does not meet the ambitious targets of the EU's Digital Decade, which calls for gigabit connectivity for 95% of households. Nevertheless, this approach is more in line with the reality of the Czech Republic, where cost-effectiveness is key and some geographically challenging areas could be covered by alternative technologies, such as FWA, which would provide a sustainable and realistic solution for the majority of the population.

The investment gap for the 90% FTTx coverage scenario is CZK 48 billion; however, coverage is lower than the Czech Republic's specified connectivity KPIs. The total cost of achieving this target is significantly reduced, mainly because the most expensive parts of the infrastructure for the remaining 10% of households are not built. This reduces not only the costs of building access networks, but also those of the local loop. The total costs for this scenario are tens of per cent lower than in Scenario 2 (95% fibre coverage), thanks to a more targeted use of resources.

This scenario envisages a gradual increase in the number of households connected via FTTx fibre-optic technology, with the aim of connecting 2,021,124 households, representing 90 per cent of all households in the Czech Republic. As shown in Table 6, new service areas and households are added each year, with coverage increasing from 51 per cent to 87 per cent between 2024 and 2029. The cumulative number of connected households will rise from 2,611,117 in 2024 to 4,630,716 in 2030. This increase reflects the expansion of the backhaul and access optical networks, which will be built primarily in more densely populated areas. The expansion of the backhaul optical infrastructure and the installation of new handover points play a significant role here. The cost of connecting households rises as construction progresses and reaches less densely populated areas, where the cost of connecting a single household increases. In 2024, the cost of connecting a single household was just under 10,000 CZK, but by 2030 these costs had risen to almost 24,000 CZK.

Figure 4: Concentration curve of total costs and the cost of connecting one household in Scenario 3



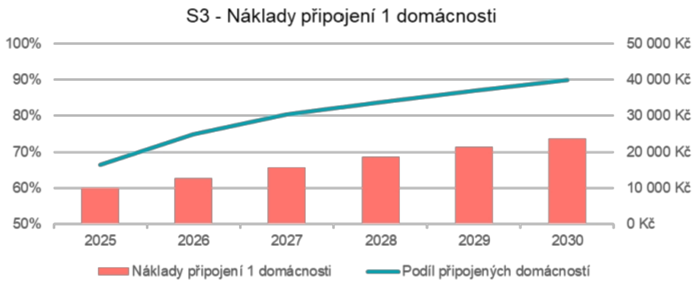


Table 6: Scenario 3. 90% FTTx coverage

Scenario 3: 90% FTTx	2024	2025	2026	2027	2028	2029	2030
Number of connected ZSJs in the given year		3,037	1,802	2,172	1,228	1,309	1,511
Total number of connected ZSJ		5,483	7,285	9,457	10,685	11,994	13,505
Number of households connected in the given year		805,526	439,585	275,549	177,399	164,407	157,133
Total number of connected households		805,526	1,245,111	1,520,660	1,698,059	1,862,466	2,019,599
Total number of connected households	2,611,117	3,416,643	3,856,228	4,131,777	4,309,176	4,473,583	4,630,716
% of households connected to VHCN	51%	66%	75 %	80 %	84%	87%	90%
km – fibre-optic		-	-	1	1	1	1
Average cost of connecting one household (CZK)		9,871	12,773	15,687	18,731	21,347	23,623
Connection costs for the year (CZK)	-	7,951,654 871	15,903,309 742	23,854,964 613	31,806,619 483	39,758,274 354	47,709,929 225

5.1.1.4 Scenario 4. Combination of FTTx & FWA: 95% coverage for a small settlement with 16 households

The fourth scenario considers a combination of FTTx and FWA technologies to achieve 95% coverage of households with VHCN technology. This scenario envisages connecting the majority of households via FTTP, which provides high-capacity connectivity in accordance with VHCN Category 1. However, for residential areas with very sparse population density, where the economic viability of building fibre-optic networks is virtually impossible, the use of FWA technology is proposed; in this specific scenario, a one-metre transmitter of a newer model is envisaged.

In this scenario, FWA technology is used for residential areas with a maximum of 16 flats, whilst households with the highest costs for backhaul and access network deployment are excluded from the analysis. FWA technology, further supported by the development of 5G networks, will gain in importance in the future due to its ability to provide connectivity over greater distances at a reasonable price-performance ratio. An important factor is that the range of FWA technology is limited by a single radio unit, which is capable of connecting approximately 16 households within the transmitter's range. However, this scenario does not take into account technical or legislative constraints, such as base station capacity or the feasibility of constructing new BTSs, which could further affect the viability of this solution. A significant limitation of this scenario therefore remains that it covers only those households where a single radio unit can be used effectively.

The total investment gap for the 95% coverage scenario, combining FTTx and FWA, is 61 billion CZK. Looking at the gradual increase in the number of connected households year on year, a cumulative total of 3,524,868 households will be connected in the first year, with this figure rising gradually to 4,889,493 connected households by 2030. This figure represents 95% of all households covered, with 99% of all households connected via FTTx and 1% via FWA; however, when looking at the proportion of connected ZSJs by technology, this ratio differs significantly, with 89% of ZSJs connected via FTTx and 11% via FWA. The cost of connecting a single household in year 1 of the simulation is approximately 11,000 CZK, but this increases over time as households in more remote and less accessible areas are connected. By 2030, the cost has risen to almost 27,000 CZK per household.

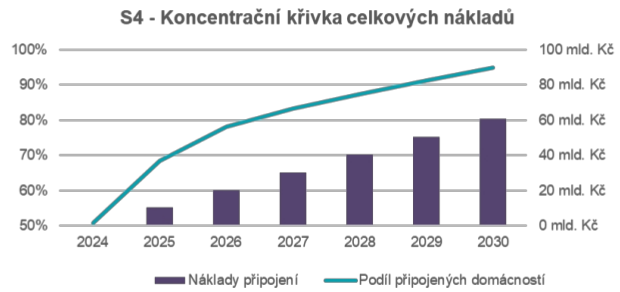
The graph below shows the concentration curve for Scenario 4, illustrating the relationship between costs and household coverage using a combination of FTTx and FWA technologies. According to data from 2023, approximately 51 per cent of households were covered by VHCN technology. In the first year of the simulation, 36 per cent of all previously unconnected households are connected; this proportion decreases in subsequent years, falling to just 7.5 per cent in the final year. With an investment of around 30 billion CZK – representing roughly 50 per cent of the total costs – over 83 per cent of all households and 47 per cent of currently unconnected rural areas will be connected.

This scenario shows that unit costs rise as coverage increases, with the final 5 per cent of households requiring a significantly higher investment. Figure 5 thus clearly illustrates that covering remote and less accessible areas using FWA remains cost-intensive, even though this technology offers certain savings compared with a purely optical solution.

In terms of costs, this option is not significantly cheaper than coverage using purely optical technology. It is estimated that approximately 11 per cent of all ZSJ (i.e. 1,723) would be connected via FWA, primarily in remote areas with very low population density. These areas are characterised by low population density, where the costs of building optical infrastructure per connection are significantly higher than in more densely populated areas. At the same time, due to these costs, these areas are very often excluded from the cost calculations in Scenario 2.

Overall, Scenario 4 is a very strict option, and the difference between cost-effectiveness and connection quality is very small here. Although FWA connections are not ideal in terms of capacity and reliability compared with fibre-optic connections, they can play a key role in efforts to cover as many households as possible in areas where the roll-out of fibre-optic networks would not be economically viable. Furthermore, the development of 5G technology will bring further benefits for the expansion and quality of FWA networks.

Figure 5: Concentration curve of total costs and the cost of connecting one household in Scenario 4



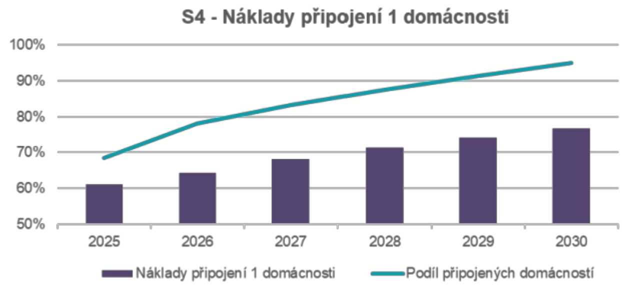


Table 7: Scenario 4. Combination of FTTx & FWA – 95% coverage for a local area with 16 households

Scenario 4: Combination of FTTx & FWA	2024	2025	2026	2027	2028	2029	2030
Total number of connected ZSJs	-	5,223	7,856	9,952	11,609	13,427	15,422
Number of connected ZSJ in the given year	-	2,777	2,633	2,096	1,657	1,818	1,995
Number of households connected in the given year	-	913,751	498,881	262,713	212,552	199,938	190,542
Cumulative number of connected households	-	913,751	1,412,631	1,675,345	1,887,897	2,087,834	2,278,376
Total number of connected households	2,611,117	3,524,868	4,023,748	4,286,462	4,499,014	4,698,951	4,889,493
% of households connected to VHCN	51%	68%	78%	83%	87%	91%	95%
ZSJ Connected via FTTx	-	3,501	6,133	8,229	9,886	11,704	13,699
ZSJ Connected via FWA	-	1,722	1,723	1,723	1,723	1,723	1,723
Households connected via FTTx	-	892,855	1,391,728	1,654,442	1,866,994	2,066,931	2,257,473
Households connected via FWA	-	20,896	20,903	20,903	20,903	20,903	20,903
Average cost of connecting one household (CZK)	-	11,075	14,327	18,120	21,440	24,234	26,649
Connection costs for the year (CZK)	-	10,119,347 500	20,238,695 000	30,358,042 500	40,477,390 000	50,596,737 500	60,716,085 000

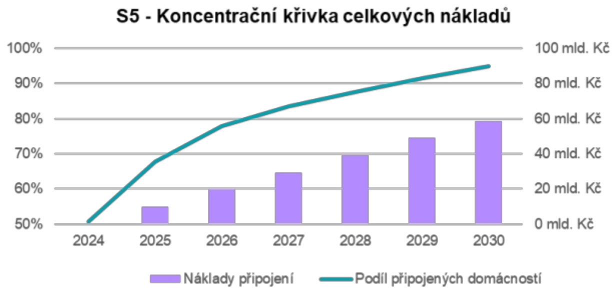
5.1.1.5 Scenario 5. Combination of FTTx & FWA: 95% coverage for a residential area with 32 households

Scenario 5 focuses on covering 32 dwellings via a two-sector radio link, with FWA technology playing a key role in reducing the cost of connecting the residential area. Although FWA enables the connection of a large number of housing estates, its impact on the overall proportion of connected households is not particularly significant, as it is primarily intended for areas with low population density where fibre-optic infrastructure is not economically viable. By utilising dual-sector radio, it is possible to cover more households and thus take a larger proportion of housing estates into account within the simulation. In Scenario 5, FWA therefore provides connectivity to less than 4 per cent of households; however, in terms of the number of service areas, it covers a significantly higher percentage, specifically 27 per cent. The scenario anticipates the connection of 32 households via dual-sector radio, which, whilst increasing the proportion of service areas connected via FWA, does not substantially affect the total number of connected households.

According to Scenario 5, the investment costs differ from those in scenarios focused on full fibre coverage. The reduction in total costs compared with Scenario 4 is 3.3 per cent, and 4.6 per cent compared with Scenario 2. The investment gap amounts to approximately 59 billion CZK. The concentration curve suggests that a large proportion of the costs is associated with the final few per cent of households, which are the most difficult to reach. FWA technology reduces connection costs in remote areas; consequently, the average connection costs per dwelling in Scenario 5 are lower than in Scenario 4. Furthermore, compared with Scenario 4, an additional 87,711 of the analysed households are connected via FWA technology in Scenario 5. The cost of connecting a single household in year 1 of the simulation is approximately 11,000 CZK, but this increases over time; by 2030, the cost is more than double that of 2025, as households in more remote and less accessible areas are being connected.

For more detailed information, see the graphs and table below.

Chart 6: Concentration curve of total costs and the cost of connecting one household in Scenario 5



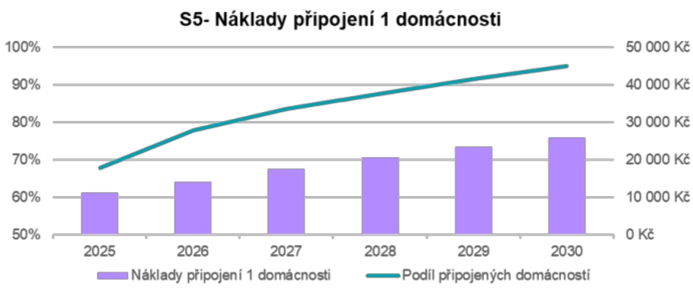


Table 8: Scenario 5. Combination of FTTx & FWA, 95% coverage for a small settlement with 32 households

Scenario 5: Combination of FTTx & FWA	2024	2025	2026	2027	2028	2029	2030
Total number of connected ZSJs	-	7,518	10,125	12,109	13,587	15,079	16,713
Number of connected ZSJ in the given year	-	5,072	2,607	1,984	1,478	1,492	1,634
Number of households connected in the given year	-	874,912	522,539	290,076	208,748	196,005	186,127
Cumulative number of connected households	-	874,912	1,397,450	1,687,527	1,896,275	2,092,279	2,278,406
Total number of connected households	2,611,117	3,486,029	4,008,567	4,298,644	4,507,392	4,703,396	4,889,523
% of households connected to VHCN	51%	68%	78%	84%	88%	91%	95%
ZSJ Connected via FTTx	-	3,134	5,612	7,595	9,073	10,565	12,199
ZSJ Connected via FWA	-	4,384	4,513	4,514	4,514	4,514	4,514
Households connected via FTTx	-	788,238	1,309,745	1,599,816	1,808,564	2,004,568	2,190,695
Households connected via FWA	-	86,674	87,705	87,711	87,711	87,711	87,711
Average cost of connecting one household (CZK)	-	11,183	14,003	17,394	20,639	23,381	25,766
Connection costs for the year (CZK)	-	9,784,108 333	19,568,216 667	29,352,325 000	39,136,433 333	48,920,541 667	58,704,650 000

5.1.1.6 Scenario 6. Combination of FTTx & FWA, 95% coverage for a municipality with 48 households

In Scenario 6, the total investment gap fell to CZK 56 billion, which is 4.6 per cent less than in Scenario 5 and just under 9 per cent less than in Scenario 2. FWA technology plays a significant role in this scenario, with 37 per cent of ZSJ connected via FWA, although this represents only 7.2 per cent of households. This discrepancy between the proportion of connected service areas and households demonstrates that FWA is effective at covering geographically extensive but sparsely populated areas, where the roll-out of fibre-optic infrastructure would be financially demanding and less profitable.

In 2025, 9,103 ZSJs are connected, with this number gradually increasing to 17,396 ZSJs by 2030. The number of ZSJs connected via FWA is high during the first three years of the simulation, suggesting greater efficiency in covering hard-to-reach areas. However, the proportion of households connected via FWA grows more slowly from the third year of the simulation onwards. Approximately 164,000 households are connected via FWA, whilst the main growth in connected households is achieved through FTTx. Even in year 1 of the simulation, the proportion of households connected via FWA is 69 per cent, compared with 31 per cent via FTTx. When looking at households, the balance is already significantly in favour of FTTx, through which 93 per cent of the analysed households are connected. The cost of connecting households in the first year of the simulation starts at 10,931 CZK, but rises over the years, primarily due to the connection of households in more remote areas, where costs increase to 24,576 CZK per household by 2030.

The graph below shows the concentration curve for Scenario 6, illustrating the relationship between costs and household coverage using a combination of FTTx and FWA technologies; over the first four years, 88 per cent of all households and 63 per cent of all ZSJ will be covered. In the first year of the simulation, 11.5% of all unconnected households are connected; this proportion decreases in subsequent years, falling to just 3% in the final year.

Figure 7: Concentration curve of total costs and the cost of connecting one household in Scenario 6

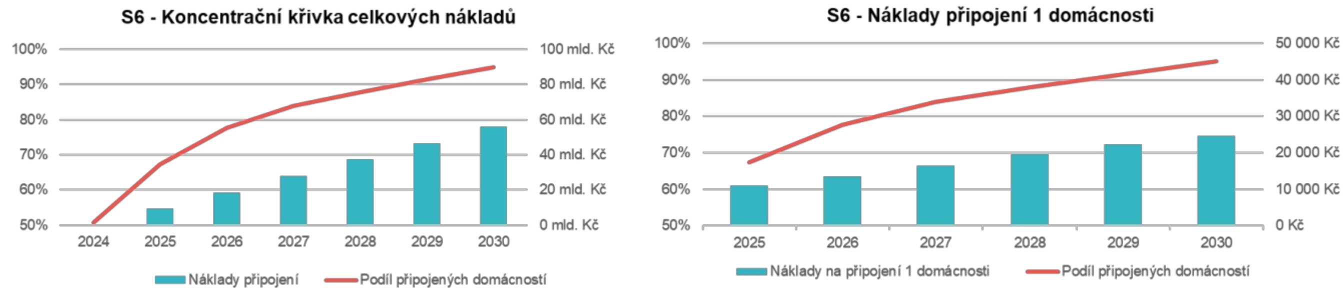


Table 9: Scenario 6. Combination of FTTx & FWA – 95% coverage for a service area with 48 households

Scenario 6: Combination of FTTx & FWA	2024	2025	2026	2027	2028	2029	2030
Total number of connected ZSJs	-	9,103	11,435	13,541	14,834	16,062	17,396
Number of connected ZSJ in the given year		6,657	2,332	2,106	1,293	1,228	1,334
Number of households connected in the given year		852,060	536,224	317,358	203,993	189,177	179,641
Cumulative number of connected households		852,060	1,388,284	1,705,642	1,909,635	2,098,811	2,278,452
Total number of connected households	2,611,117	3,463,177	3,999,401	4,316,759	4,520,752	4,709,928	4,889,569

% of households connected to VHCN	51%	67.29%	78 %	84%	88%	92%	95%
ZSJ Connected via FTTx		2,793	4,986	7,089	8,379	9,607	10,936
ZSJ Connected FWA		6,310	6,449	6,452	6,455	6,455	6,460
Households connected via FTTx		689,276	1,224,377	1,541,715	1,745,690	1,934,866	2,114,482
Households connected via FWA		162,784	163,907	163,927	163,945	163,945	163,970
Average cost of connecting one household (CZK)		10,953	13,445	16,415	19,549	22,233	24,576
Connection costs for the year (CZK)	-	9,332,650 000	18,665,300 000	27,997,950 000	37,330,600 000	46,663,250 000	55,995,900 000

5.1.1.7 Scenario 7. Combination of FTTx & FWA: 95% coverage for a residential area with 62 flats

The final option, combining FTTx and FWA connections to cover 95% of households, utilises a 4-sector transmitter capable of providing VHCN connectivity to up to 68 households. This variant assumes that wherever it is more cost-effective to build or equip a base station, and provided there are no more than 68 households in the area in question, coverage will be provided via FWA. In the simulation, this means that 45 per cent of service areas will be connected using FWA technology and 55 per cent using FTTx; however, as noted above, this breakdown is entirely different when examining the coverage technology in detail at the household level: 89 per cent of households will be covered by fibre-optic technology, compared with 11 per cent which will achieve VHCN-quality connectivity via FWA technology. By the third year of the simulation, connections via FWA predominate, precisely due to the low connection costs; this is also illustrated by the fact that in Year 1, 53 per cent of all ZSJ and 67 per cent of the total number of households are connected. A total of 17,842 ZSJ will be connected by 2030. Compared with Scenario 4, 220,000 more households are connected via FWA technology in this scenario.

The total investment gap in this scenario is the lowest of all scenarios that assume the set KPIs will be met, amounting to less than 53 billion CZK; this is 16 per cent less than the costs in Scenario 2 and 14 per cent less than in Scenario 4. Under this scenario, the concentration curve for household connections is the highest of all scenarios apart from Scenario 1; in the first year, over 16 per cent of all unconnected households (843,000) will be connected, in the second year around 10.5 per cent (540,000), and in the final year (2030) the remaining three per cent of unconnected households. The cost of connecting a single household is approximately 10,000 CZK in year 1; in year 2 of the simulation, this rises more significantly to 13,000 CZK, and over the following two years (up to 2028) it increases at a rate of around 20 per cent per annum. The rate of growth then slows, and in the final year the average cost of connecting a single household is around 23,000 CZK per annum. Overall, this is the variant with the lowest total investment gap and the lowest connection costs per household. This is the scenario in which the highest number of ZSJs are connected – nearly 18,000, which is 14 per cent more than in Scenario 4 and 7 per cent more than in Scenario 2. This is because priority was given to ZSJs with a relatively lower number of households; in this scenario, the ratio of households per ZSJ is 7,128, compared with, for example, 148 households per ZSJ in Scenario 4.

For more detailed information, see the graphs and table below.

Chart 8: Concentration curve of total costs and the cost of connecting one household in Scenario 7

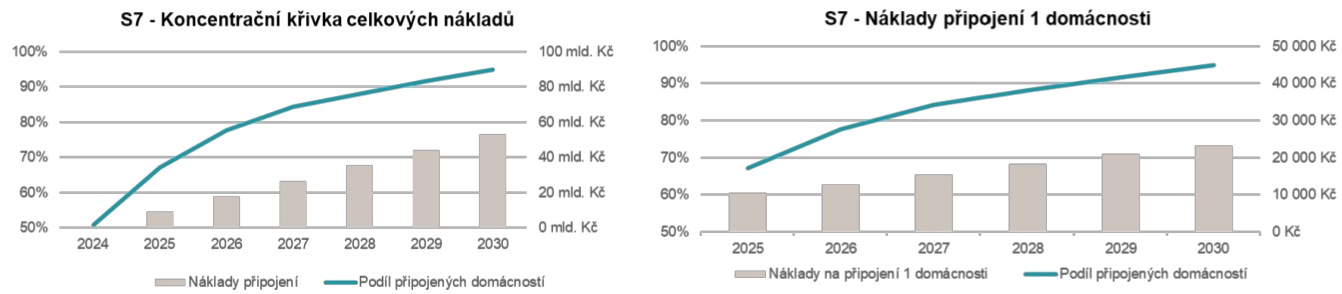


Table 10: Scenario 7. Combination of FTTx & FWA, 95% coverage for a residential area with 62 flats

Scenario 7: Combination of FTTx & FWA	2024	2025	2026	2027	2028	2029	2030
Total number of connected ZSJs	-	10,104	12,350	14,579	15,702	16,734	17,842
Number of ZSJ units connected in the given year	-	7,658	2,246	2,229	1,123	1,032	1,108
Number of households connected in the given year	-	842,987	539,757	343,870	198,293	181,609	171,901
Cumulative number of connected households	-	842,987	1,382,744	1,726,614	1,924,907	2,106,516	2,278,417
Total number of connected households	2,611,117	3,454,104	3,993,861	4,337,731	4,536,024	4,717,633	4,889,534
% of households connected to VHCN	51%	67%	78%	84%	88%	92%	95%
ZSJ Connected via FTTx	-	2,488	4,400	6,622	7,742	8,773	9,881
ZSJ Connected via FWA	-	7,616	7,950	7,957	7,960	7,961	7,961
Households connected to FTTx	-	600,373	1,137,241	1,481,060	1,679,335	1,860,938	2,032,839
Households connected via FWA	-	242,614	245,503	245,554	245,572	245,578	245,578
Average cost of connecting one household (CZK)	-	10,470	12,766	15,335	18,340	20,949	23,242
Connection costs for the year (CZK)	-	8,825,910 833	17,651,821 667	26,477,732 500	35,303,643 333	44,129,554 167	52,955,465 000

5.1.2 Coverage of local service areas without a backhaul network

To analyse the investment gap, we calculated the costs of the backhaul network only for those ZSJs in which no backhaul connection is recorded according to BCO statistics, i.e. 1,206 ZSJs, as those ZSJs where there is not a single household were excluded from the analysis. When calculating costs, we considered only the costs associated with building the backhaul network to the relevant ZSJ. The costs of connecting households are included in Scenario 1, as this represents the calculation of the investment gap for connecting all households and ZSJs using a purely optical network. In the simulation, we used a linear distribution of network roll-out over time, with those ZSJs exhibiting the lowest costs – represented by the shortest distance to the nearest ZSJ with a backhaul connection – being connected in the first year. The specific results and procedure for connecting individual ZSJs and households within a given ZSJ are described in the relevant scenarios in section 5.1.1 above. The calculation procedure followed the methodology described in section 4.3. The simulation of backhaul network connection is illustrated in Figure 2 below. The graph illustrates iterative connection over the years based on the distance to the nearest PoP of the backhaul network. The number of connected ZSJs remains the same for each year, i.e. 17 per cent of all unconnected ZSJs.

Table 11 below summarises the key findings of the analysis of ZSJ connectivity. In the event that all ZSJs are connected in accordance with Scenario 1 (via optical backhaul), the total cost of this option is 1.7 billion crowns and the total length of the backhaul network built to all ZSJs is 2,053 km.

Given the demographic characteristics of unconnected rural areas and households, it cannot be expected that commercial roll-out will take place without public support in these areas, where backhaul infrastructure for high-capacity connectivity has not yet been built. In these areas, it is essential to create incentives for the development of VHCN connectivity, primarily through targeted grant schemes and support for the construction of the necessary infrastructure. These subsidies should include not only support for the roll-out of fibre-optic networks, but also the provision of wholesale access to the infrastructure built. This will enable greater competitiveness and access for smaller service providers. It is crucial that these incentives reflect the fact that, without public support, investment in these areas would be economically unsustainable.

Table 11 Scenario 1. Costs of building backhaul connections

Cost per km of fibre (million CZK)	2025	2026	2027	2028	2029	2030	Total
Dense population	3.2	1.8	-	1.1	-	-	
Medium populati on density	55.7	18.6	11.0	4.5	8.3	-	
Sparse population	265.2	292.9	288.6	290.1	272.9	164.5	
Total (million CZK)	**324.1**	**313.3**	**299.6**	**295.7**	**281.3**	**164.5**	**1,678.5**
Covered by ZSJ	214	215	215	215	214	133	1,206
Laying of optical cables (km)	380	383	370	367	348	206	2,054

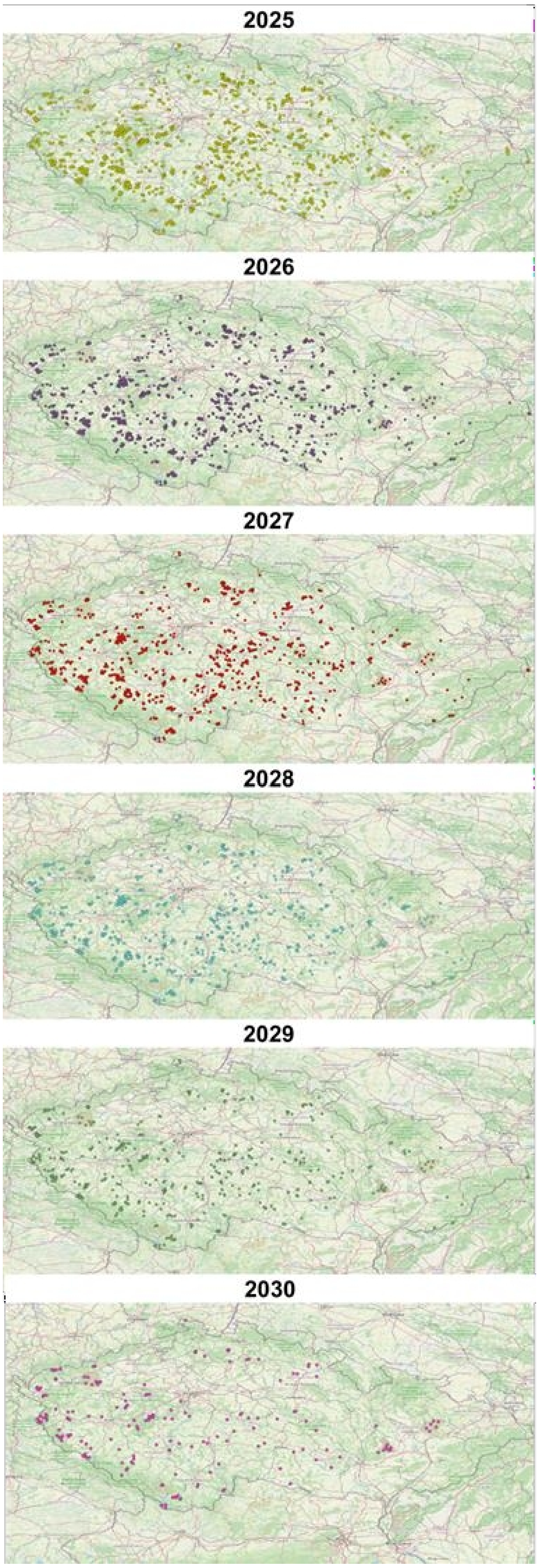


Figure 2: Simulation of ZSJ backhaul network coverage

6 Summary of connection scenarios

This chapter focuses on summarising and comparing the individual scenarios for connecting households to VHCN networks. All scenarios show a similar trend in line with the law of diminishing returns, which indicates that the cost of connecting households rises significantly as we move into more remote and sparsely populated areas. Significant differences between the scenarios are particularly evident in Scenario 1, where it is necessary to build not only an access network but also a backhaul network to all service areas that are not yet connected.

To facilitate a better understanding and comparison of the various approaches, this chapter focuses primarily on Scenario 2 and Scenario 7, which represent the two most distinct scenarios whilst also meeting the key performance indicators (KPIs) for the Czech Republic in the area of connectivity:

- Scenario 2 focuses on maximising fibre-optic connectivity using FTTx technology, whereby all remaining households not connected to the VHCN are covered by this fibre-optic infrastructure. This scenario involves the highest investment costs due to the extensive roll-out of not only access but also backhaul networks, which are essential for achieving coverage in remote locations. However, this approach ensures the highest quality of connection with the possibility of future upgrades.
- Scenario 7 presents an alternative model in which households, where technically feasible, connect to the VHCN using wireless technologies, in particular FWA. In the context of the Czech Republic, where wireless technology already plays an important role, accounting for more than 5 per cent of VHCN connections (according to the DESI 2023 report), this scenario presents an effective and less costly alternative to fully optical connectivity. Scenario 7 is therefore an option that combines lower costs with technical feasibility in areas where fibre-optic infrastructure would not be economically viable.

In summarising these scenarios, attention will be focused primarily on the economic differences between the two models, their impact on achieving connectivity targets, and the potential for using a combination of technologies in different types of locations. This approach enables better planning of investments in network development and provides insight into the advantages and disadvantages of individual scenarios in the context of infrastructure and the need to meet European and national digital transformation targets.

The number of household connections is almost identical, with differences in the absolute number of household connections being due to variations in the population density of the analysed statistical areas; however, in both scenarios, 95 per cent of households are connected, accurate to the nearest tenth of a per cent. In Scenario 2, the investment gap is 14 per cent higher than in Scenario 7, which utilises FWA. This difference is due to higher investment costs for the construction of access networks, which are necessary to achieve coverage in remote areas. In year 1 of the simulation, almost twice as many ZSJs are connected in Scenario 7 as in Scenario 2; however, this does not lead to a higher number of connected households – there are 100,000 fewer than in Scenario 2. However, over time, the number of connected ZSJs evens out; indeed, in the final year of the simulation, twice as many ZSJs are connected in Scenario 2 as in Scenario 7. A similar trend can then be observed for both scenarios in terms of the number of connected households. Scenario 2 offers the highest quality of connection, but at the cost of higher investment costs.

Conversely, Scenario 7 combines lower costs with technical feasibility, which is reflected in a higher number of connected localities and households in the early years of the simulation. The choice between these two scenarios depends on priorities – whether to prioritise quality and future network capacity (Scenario 2), or faster and less costly coverage (Scenario 7). It is interesting to look at the average number of connected households per ZSJ in a given year. In Scenario 2, where access network costs are derived from population density and the resulting length of access network connections, it can be seen that the areas (ZSJs) with high population density are connected first. In Scenario 2, the average number of households in a given ZSJ in Year 1 is 159, whilst in Scenario 7 it is ‘only’ 83. However, this ratio reverses significantly from the third year of the simulation onwards, and by the end of the simulation (2030), the ratio is completely reversed, with the number of households per ZSJ in Scenario 7 being more than 93 per cent higher than in Scenario 2. The situation in year 2 of the simulation is also interesting, as both scenarios show the highest absolute number of households per ZSJ (184 for Scenario 2 and 240 for Scenario 7); in other words, the ZSJs with the highest population density are connected.

When comparing the costs of connecting a single household in Scenario 7, which average nearly 17,000 CZK per year, with those in Scenario 2, where the average annual cost of connecting a single household is more than 19,000 CZK, the difference in average connection costs per household is more than 13 per cent lower in Scenario 7. Scenario 7, in which the majority of

ZSJs are connected via

FWA (almost 80 per cent of all connected households in the first year), has almost identical costs per household connection in Year 1. However, this difference gradually increases each year, and by the sixth year of the simulation, the difference in the cost of connecting a single household stands at 14 per cent.

When analysing the investment gap and comparing the two most relevant scenarios, it is clear that the households from the first two years of the simulation – namely 8,600 households in Scenario 2 and 12,400 in Scenario 7 – represent those with the highest commercial connection potential; corresponding to 69 per cent of all households in the Czech Republic in the case of Scenario 2 and 67 per cent in the case of Scenario 7, which have the potential for commercial connection. Conversely, the further we progress in the simulation, the more we encounter ZSJs with such a low population density that the idea of organic (purely commercial) connectivity is unthinkable.

The general differences between Scenarios 2 and 7 are illustrated in Table 15 below:

Table 12: Comparison of the results of simulations S2 and S7

Comparison of simulation outputs S2 and S7 **Number of connected ZSJs in the given year**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Scenario 2: FTTx 95%	5,957	8,576	10,509	12,164	14,239	16,608
Scenario 7: FTTX and FWA 95%	10,104	2,246	2,229	1,123	1,032	1,108
Difference between S7 and S2 (%)	70%	-74%	-79%	-91%	-93%	-93%
Number of connected households in the given year						
Scenario 2 FTTx 95%	949,983	481,380	244,174	212,084	199,769	189,527
Scenario 7: FTTx and FWA 95%	842,987	539,757	343,870	198,293	181,609	171,901
Difference between S7 and S2 (%)	-11%	12 %	41 %	-7%	-9%	-9%
Connection costs per household						
Scenario 2 FTTx 95%	10,791	14,324	18,355	21,724	24,556	27,014
Scenario 7: FTTx and FWA 95%	10,470	12,766	15,335	18,340	20,949	23,242
Cost difference between S7 and S2 (%)	-3%	-11%	-16%	-16 %	-15%	-14%
Average number of households per ZSJ						
Scenario 2 FTTx 95%	159	56	23	17	14	11
Scenario 7: FTTx and FWA 95%	83	240	154	177	176	155
Difference in the average number of household connections (%)	-48%	328 %	564 %	913 %	1,154 %	1,260%

If we look at all the households analysed from a broader perspective, our data currently shows that 51 % of households are currently covered, but we are unable to distinguish which technology these households are connected via. According to data from DDPP[61] , coverage by very high-capacity networks (VHCN) stands at 55.8 per cent, of which 5.3 per cent is provided via FWA technology. As our data is based on a VHCN coverage rate of 51 per cent, this figure is for guidance only (see Section 4.3.2 – Constraints and Limitations). As it is not possible to determine precisely the VHCN connection technology at household level in the Czech Republic, we have used a share of VHCN connections via FWA of 5.3% for our analysis of connection scenarios and calculation of the investment gap; this represents approximately 10% of the total current VHCN connections.

[61][61]https://digital-strategy.ec.europa.eu/en/library/digital-decade-2024-broadband-coverage-europe-2023

In our simulation for Scenario 7, a further 250,000 households would be connected via FWA by the end of 2030. If we were to proceed according to this investment gap scenario, a total of 400,000 households would be connected to VHCN via FWA by the end of the simulation in 2030, representing almost 8 per cent of all households included in the projection. This development not only increases the relative share of households connected via FTTx technology, but also demonstrates that the scenario is consistent with the historical development of FWA networks, which supports its relevance and sustainability in the future.

FTTx connections would thus total nearly 4.9 million households by the end of our simulation in Scenario 2, where 95 per cent of unconnected households are covered by FTTx. In Scenario 7, where (more in line with reality) connections would also be made using FWA technology, more than 2 million households would be connected via FTTx and the remaining 245,000 via FWA.

7 Conclusion

Compared with the 2019 study[62], in which the investment gap for connecting all unconnected households via fibre-optic technology was estimated at 97 billion CZK, the current estimate of the investment gap for achieving 100 per cent coverage of VHCN households stands at 83 billion CZK. This decrease is logically due to the higher proportion of connected households; however, the current estimate is only just under 15 billion lower than in 2019, This is primarily due to higher connection costs, VHCN technical requirements, and, in particular, changes in demographic data, as between the 2011 and 2021 censuses there was an increase in the number of households, a rise in the number of OBAMs per dwelling, and a decrease in the average number of inhabitants per household.

Given the defined objectives of this study, the main findings **relate to the optimised** (yet ambitious) **KPIs for the Czech Republic in the area of connectivity, with the aim of covering 95 per cent of all households under the VHCN category.** In our definition of the investment gap, the input parameters for determining the investment gap are therefore based on two main scenarios: a scenario in which 95 per cent of households are connected in accordance with VHCN parameters using only a fibre-optic (FTTx) network, and a variant in which FWA technology is utilised in identified locations suitable for coverage via FWA. This included ZSJ areas with lower population density and a maximum of 16–64 households, according to scenarios 4 to 7, which differ in the number of sector transmitters and the capacity to serve the given locations. In terms of the investment required for an accessible connection, locations with the least favourable economic conditions were excluded from the total investment; this includes areas with low population density and a great distance from the nearest access network.

When comparing the two most dissimilar scenarios (2 and 7), which meet the Czech Republic's KPIs, **the investment gap** was **determined to be CZK 61.5 billion for scenario 2**. **In scenario 7, the investment gap was calculated at CZK 53 billion.**

In Scenario 2, which focuses solely on connecting unconnected households using FTTx technologies, approximately 4.9 million households would be connected via FTTx by the end of the simulation in 2030. This scenario offers the highest quality of connection and future network sustainability, albeit at the cost of higher investment costs and a slower pace of roll-out in the early years. In terms of the cost of connecting a single household, the average cost in Scenario 2 is 14% higher than in Scenario 7. Overall, therefore, coverage in Scenario 2 is slower over the course of the simulation, but is concentrated in areas with higher population density, which yield a higher return on investment.

Scenario 7 was chosen as an efficient and more cost-effective alternative to a fully optical infrastructure, which is reflected primarily in lower investment costs and faster coverage of more remote areas. Compared with Scenario 2, which focuses on maximum coverage with optical infrastructure, Scenario 7 shows a 14% lower investment gap, a significant difference caused by the higher costs of constructing optical networks, particularly in more remote locations. Furthermore, in Scenario 7, over 1,000,000 ZSJs are connected, although the number of connected households is broadly the same. In terms of the cost of connecting a single household, Scenario 7 is cheaper in the early years. In 2025, the average connection costs in both scenarios are almost equal, with costs per household 3 per cent lower in Scenario 7. Over time, however, this difference increases, and by 2030 the average connection costs in Scenario 7 are 14 per cent lower than in Scenario 2.

The analysis also included a definition of the investment gap for connecting the backhaul networks of those basic settlement units (BSUs) that are still not connected to this network. Based on an analysis of input data from BCO, we found that, of the total number of basic settlement units (BSUs) in the Czech Republic, 1,206 BSUs remain unconnected (49 ZSJs were excluded from the analysis as not a single household was registered in them), representing 1.56 per cent of all households, or approximately 80,500 households. To connect 100 per cent of these ZSJs via FTTx, it will be necessary to build approximately 2,054 kilometres of optical infrastructure, with the total cost of constructing the backhaul estimated at 1.7 billion CZK (FTTx connections).

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[62]https://www.mpo.gov.cz/assets/cz/e-komunikace-a-posta/elektronicke-komunikace/koncepce-a-strategie/narodni-plan-rozvoje-siti-nga/2020/2/Final-report_GTA_12_12_2019.pdf

Overall, it can be said that Scenario 2 is a suitable choice for densely populated areas and for the long-term development of robust, high-quality infrastructure capable of fully meeting future data transmission demands. Scenario 7 represents an effective combination of technologies that enables rapid and more cost-effective coverage, particularly in the early years. According to this scenario, by 2030, 95 per cent of households in the Czech Republic would be connected to VHCN networks, with around 11 per cent of currently unconnected households being connected via FWA technology, representing approximately 250,000 households. This scenario roughly corresponds to the real potential of wireless technology in the Czech context, where FWA technology already plays a significant role in VHCN connectivity; according to data published as part of ‘Broadband Coverage in Europe 2023’, approximately 5 per cent (240,000) of the total number of households are connected via VHCN FWA.

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