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Conference Paper

The role of the satellite market in provisioning broadband access in Europe up to 2030

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The role of the satellite market in provisioning broadband access in Europe up to 2030

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Introduction

The European Commission's Digital Decade programme strives to guarantee access to gigabit-capable broadband for all Europeans, considering it as a core utility. However, given the geographical and demographic characteristics of Europe, some areas across the continent are likely to remain outside the footprint of high-bandwidth fixed technologies like FTTP and/or high bandwidth ground based mobile services like 5/6G by 2030.

At the same time, we see the announcement and launch of multiple new satellite constellations with the potential to offer high-bandwidth satellite internet services in the European market, including the European Union's own IRIS² programme. This opens up the prospect of a significant level of availability of (theoretically gigabit) high-speed broadband in 2030 from satellite service providers.

The last sets of targets for coverage of Europe specified by the EC; basic broadband for all by 2013 [1] and more recently from 2020 at least 30 Mbps for all [2], were only met due to satellite coverage. Historically from geosynchronous satellites but increasingly now from lower orbits with constellations to guarantee continuity as they process around the world.

For this purpose, Point Topic and its European subsidiary, Expert Intelligence, present a model to forecast the 'Satellite Gap' in Europe.

Fixed broadband coverage, particularly FTTP and DOCSIS 3.1¹ are forecasted to 2030, based on a time series of NUTS3²-level coverage from 2011 to 2021. Coverage is distributed down to a square-kilometre grid developed by Point Topic, which allows forecasting using more granular demographic data and inputs. A Gompertz model, an asymmetric sigmoid logistic growth function, is used to project future fixed broadband coverage at the square-kilometre level. Land use data, official publications on broadband rollout and connectivity in Europe, as well as our own analysis thereof are used to generate scenarios and further control the trajectory of forecasted coverage. We present three scenarios as part of this model, the first two of which (Scenario 1, 2) are controlled, while the third (Scenario 3) is based purely on 2011 – 2021 time series of coverage and the Gompertz function, without additional inputs.

The Gompertz model provides 2030 estimates of FTTP (fibre) and DOCSIS 3.1 (cable) coverage, which are weighted and aggregated back to NUTS3-level, giving a prediction for how regions and countries will compare in terms of future high-bandwidth fixed (terrestrial) broadband coverage. VHCN ('Very High Capacity Networks') coverage is then derived as a sum of FTTP and DOCSIS 3.1 coverage, with an assumption for overbuild. By identifying those areas that fall outside the fixed boundary, and assuming full European coverage by at least one consumer satellite network, we can quantify the size of a potential satellite internet market.

The authors have reviewed and integrated relevant data inputs, and extend assessments across additional non-member states in Europe (the UK, Switzerland, Norway) using proxy data where model inputs were unavailable.

¹ Which acts as a proxy for the wider cable network incl. future upgrades to DOCSIS 3.x/4

² EU-wide geographic classification system - see <https://ec.europa.eu/eurostat/web/nuts/background>

Summary

Gigabit broadband, at least 1 Gbps bandwidth downstream, available to all is a key objective of the European Union and European states overall. The target has been part of the landscape in most areas for a number of years now. There are variations in exactly when and how this coverage objective is expected to be reached. Our modelling of the extent of the deployment of fixed networks and the resulting and inevitable gaps in that coverage result in between 33 and 71 million people (6.2% to 13.6% of total population)³ without access to gigabit-capable technologies, or 480 thousand to 1.7 million square kilometres⁴ of land where fixed rollout of 1Gbps-capable technologies will not be completed.

In common with previous targets and outcomes we expect those gaps to be addressed in large part by satellite broadband services. Our modelling suggests a potential market size of between EUR 3.8 million and 8.1 million.

³ Based on 2021 populations and 2030 VHCN coverage, model Scenario 1 & 3

⁴ Based on count of kilometre-grid squares with 2030 VHCN coverage < 80%, model Scenarios 1 & 3

Background and Data

Fixed Broadband Rollout – European Policy

The past decade has seen various iterations of policy at the European level with the goal of furthering and aligning the rollout of broadband infrastructure by member states closer to each other. We will cover some key policies in this section.

In 2014, the Broadband Cost Reduction Directive (BCRD) [3] targeted the integration of existing physical broadband infrastructure and efficient deployment of new infrastructure by EU Member States. However, there have been issues with the successful implementation of the directive (most measures remained optional, little harmonisation of policy was achieved) and a review was launched in 2020.

In light of the changing technology landscape, a European Electronic Communications Code (2018) [4] and Gigabit Infrastructure Act [5] have been launched by the European Commission to coordinate efforts on the deployment of 5/6G and Fibre/VHCN networks. The benefits of achieving such targets are plenty, including efficient roll-out and reduced bureaucracy, increased cross-border investment, establishment of cross-border networks (e.g. for autonomous driving), and economies of scale for stakeholders. Unlike the earlier BCRD, which was implemented as a directive (Member States decide individually on implementation), the Gigabit Infrastructure Act will be implemented as a regulation (targets are legally binding with less room for divergence).

The work also continues at BEREC⁵ to move towards a single telecoms market across the member states. As with the BCRD and Gigabit Infrastructure Act, regularisation of policy and best practice are key elements in making this, at least theoretically, possible. Nonetheless there are significant barriers to overcome, particularly political, which will make this a slow process and without any guarantees of the level of success.

The current Digital Decade [6] programme sets targets for 5G and fibre, to meet objectives for skills provision, digital participation and digitalisation of businesses and public services by 2030. Specifically, it sets out an ambitious goal of gigabit-connectivity for all citizens. Key performance indicators and an annual report on the "State of the Digital Decade" will monitor progress.

Finally, the Connectivity Toolbox [7] of best practices for the improved deployment of VHCNs sets out a list of best practices for member states. These best practices (BPs) are intended to provide a framework for the efficient and cost-effective deployment of networks and we have included the scoring of each state's progress as an input to the outcomes we expect by 2030. We make use of the Connectivity Toolbox BPs, as well as the self-published Implementation Reports [8] released by member states in May 2022, to form the basis of our assessment of 'national ambition' for continued roll-out of VHCN technologies.

⁵ See <https://www.berec.europa.eu/en/berec/tasks>

Fixed Broadband Coverage in Europe Today

The roll-out of gigabit capable broadband networks is progressing at different rates across Europe. Large countries, including France, Germany, Italy and the UK, are still far from reaching full coverage of what the EU generally refers to as VHCNs. Others, like Spain, Romania and the Netherlands, are much closer to their targets. 2021 VHCN coverage across regions in Europe is shown on Figure 1 below.

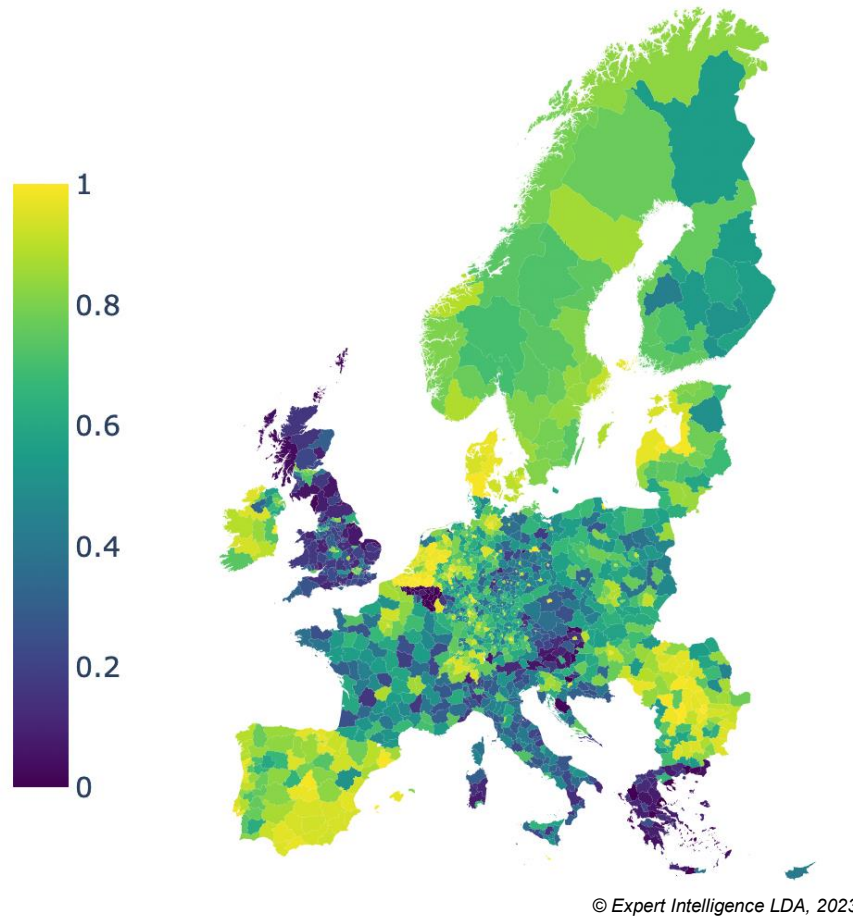


Figure 1: VHCN Coverage in Europe (2021)

The below table shows VHCN and NGA ('Next Generation Access' – referring to those technologies with above 30Mbps downstream bandwidth) by European country, with Malta leading the way and Greece currently with lowest VHCN coverage. We see a wide range of values and the differences in scale of the challenge to reach full roll-out becomes apparent.

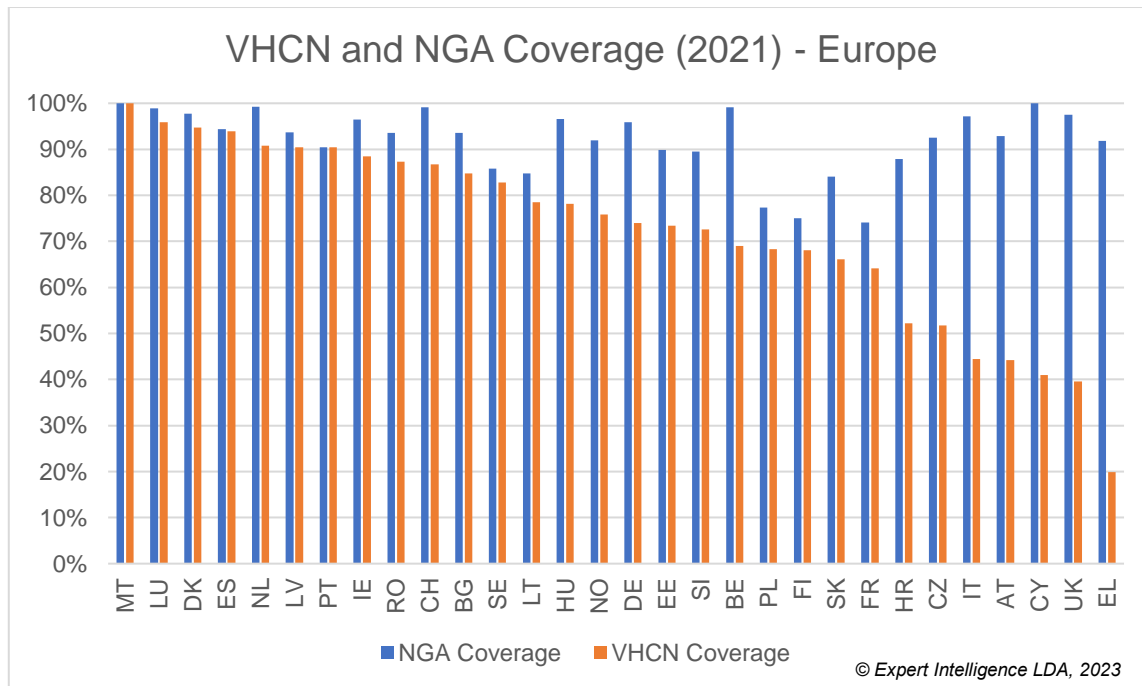


Figure 2: VHCN and NGA Coverage (2021) - Europe

Proprietary broadband coverage data at NUTS3-level was used as the primary source of broadband coverage data. For this model, we have focused on FTTP (Fibre-to-the-premises) and cable (DOCSIS 3.1, likely upgraded to DOCSIS 4 by 2030), which will provide mass-market capable high-bandwidth fixed broadband coverage until 2030, and are commonly referred to within a European policy context as VHCN. FTTP relies on fibreglass connections reaching all the way to the premises of the end-user, while DOCSIS 3.1 is an advanced protocol for high-bandwidth data transmission via cable and FTTP (using RFoG) infrastructure. Data on DOCSIS 3.1 coverage is only available to the authors from 2019 onwards.

All broadband data refers to availability data, i.e. the proportion of the population within an area which is able to access immediately or with little additional installation work a certain type of broadband technology. The data does not provide an estimate on the proportion of population actually using a certain technology (commonly referred to as 'take up').

This update builds on an original model developed by Point Topic, and is still used as the basis for common input analysis in projects with the European Commission, most notably Broadband Coverage in Europe. Data collection occurs with the involvement of ISP (Internet Service Providers) and national regulators at the member state level for all European Union member states, as well as non-EU members like the United Kingdom, Switzerland and Norway. The data is used in European Commission publications including the annually published BCE study [9].

Assessing and Ranking Countries: A Review of Current Progress and Disparities

Implementation Toolbox Scores and ‘National Ambition’

We use the Connectivity Toolbox, a collection of Best Practices defined by the European Commission, as well as the self-published Implementation Reports by member states, as a measure of ‘national ambition’ towards national broadband roll-out. In order to provide a standard input we have reviewed each submission and the country’s own assessment of their implementations and assigned a score for each BP implemented (1), in progress (0.5) or missing/not started (0). There is one further intervention for those BPs that the country reported no measures planned (NOM), generally because they have regulation and systems in place that meet the requirements of the BP.

This results in the raw and adjusted ‘scores’ below.

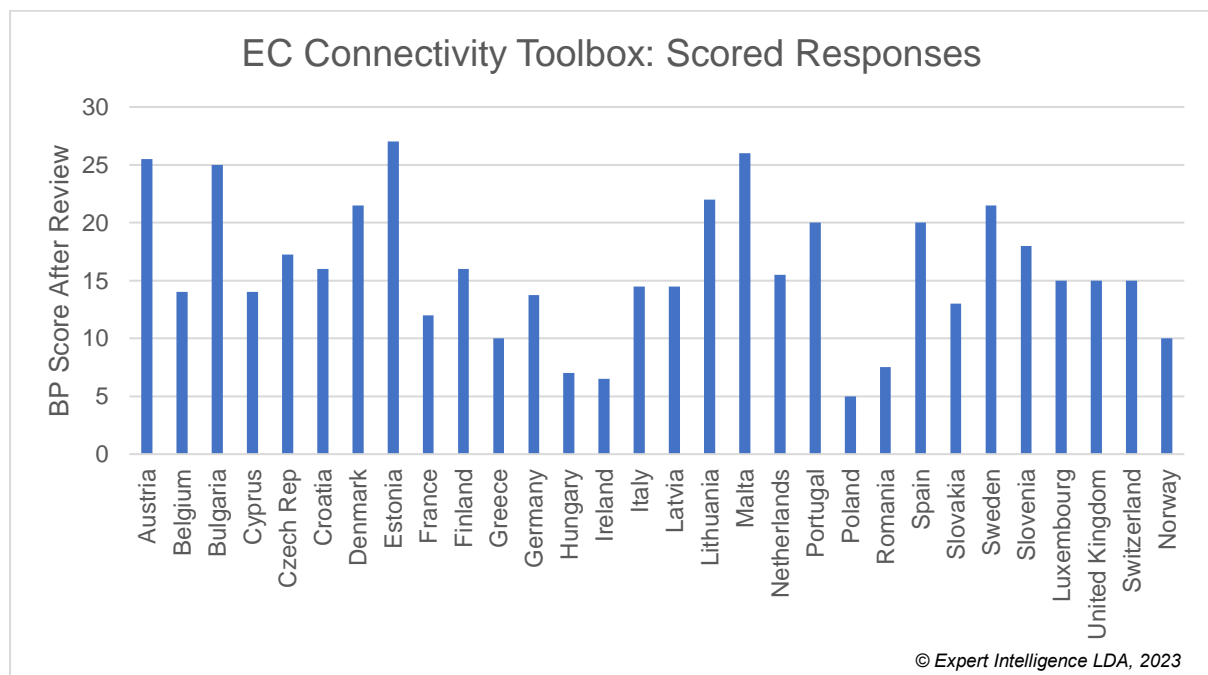


Figure 3: Connectivity Toolbox: Scored Responses

Comparing the scores achieved in terms of the implementation of BPs versus current coverage gives us a first view of the challenges faced and the readiness to address those challenges. While many states, Austria for example, score very well they have varying coverage today. This metric was used by us to estimate the level of ‘national ambition’ per country, and after our ‘scoring’ method was applied, this was only adjusted by the authors for France, Italy, Luxembourg, the UK, Norway and Switzerland, as these countries either did not submit an Implementation Report at the time of writing (Italy, Luxembourg), submitted it in a non-standard format (France), or are not EU nations (UK, Switzerland, Norway).

VHCN Coverage (% , 2021) vs Implementation Toolbox Score (actual)

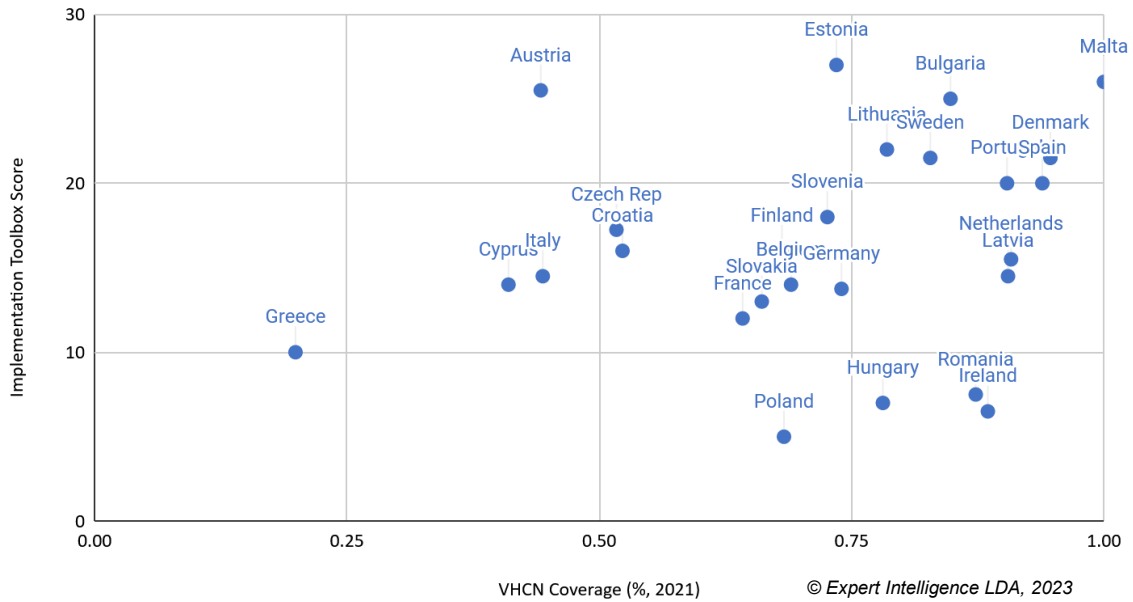


Figure 4: VHCN Coverage (2021) vs. Implementation Toolbox Score

We are able to group countries by perceived score and VHCN coverage, as below:

VHCN Coverage (2021) vs Implementation Toolbox Score (actual)

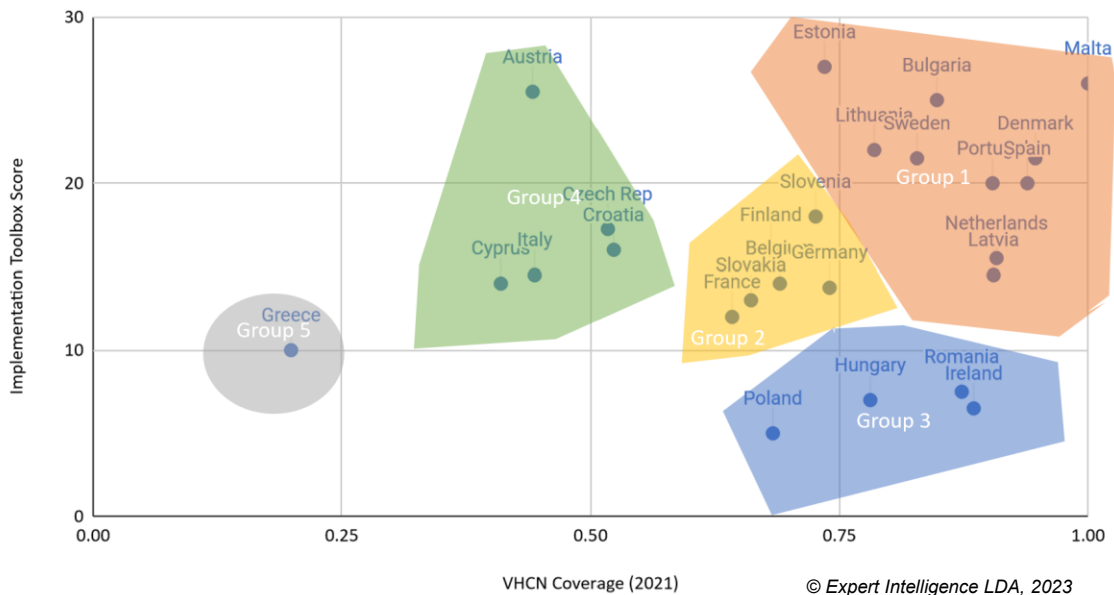


Figure 5: Connectivity Toolbox Scores and VHCN Coverage (2021)

We end up with five distinct groups based on their toolbox scores and the current coverage of VHCN networks.

Group 1 - high coverage and high toolbox/ambition scores - legislation is in place to enable broadband deployments. Information portals, planning and infrastructure access, coordinated and supported by the regulator and government.

Group 2 - typically lower coverage and lower scores than Group 1 but still on the path to maximising gigabit availability. Relatively minor elements of legislation still in process but otherwise still strongly supportive of deployments and the mechanisms needed.

Group 3 - relatively high coverage but lower toolbox scores. May not have enough legislation in place to push coverage through the country as quickly as others and risks of stalling.

Group 4 - lower coverage of VHCN networks and plenty to do in order to get a gigabit to all the population. There may be some geographic barriers (mountainous regions for example) that slow deployment or other factors that have slowed coverage to date. Complex regulatory environments as well as historical deployment dead ends or compromises have featured in the development of the Group 4 countries.

Group 5 - Greece is a particular outlier. Challenging geography, ageing legacy network missing infrastructure and a major financial crisis all contributed to low VHCN coverage in Greece today. They are moving forward with their regulatory and legislative frameworks but there is still room for improvement.

These scores and starting points give an idea of the challenges each state faces in completing their fixed roll-outs for gigabit capable networks for their populations.

Digital Economy and Society Index

A European measure of digital ‘readiness’ also exists in the form of the DESI (Digital Economy and Society Index) [10], which scores countries by a variety of indicators. DESI scores are useful because they provide a measure of digitalisation at the social level. We do not consider the ‘Connectivity’ component of the index, as this is in turn partially based on fixed broadband connectivity. This score will be used as part of our model as the ‘DESI Score’ factor.

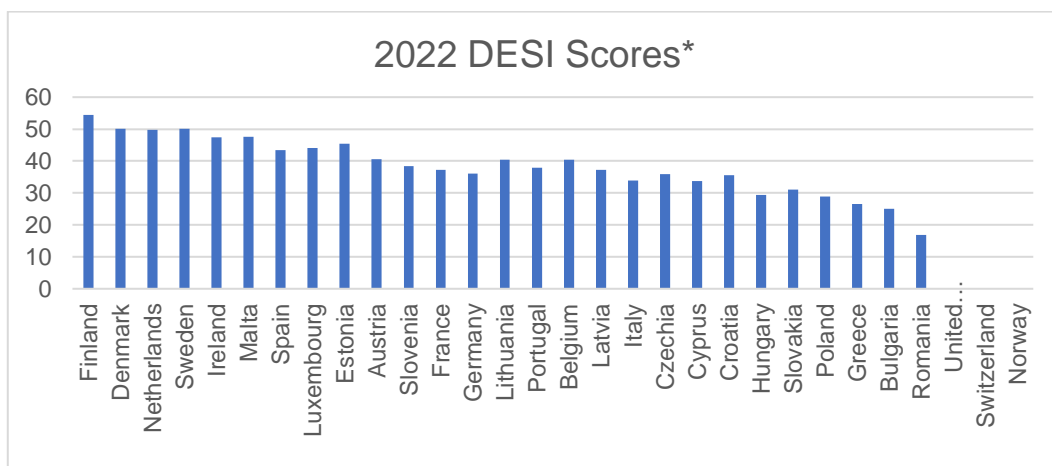


Figure 6: 2022 Digital Economy and Society Index Scores
 * = excl. 'Connectivity' Component; no score for UK, Switzerland, Norway

2025 Gigabit Society NBP Survey

The 2020 survey [11] of NBP (National Broadband Plans) of EU member states on their expectation of reaching 100Mbps bandwidth for all citizens by 2025 serves as a suitable interim target on the way to reaching the 1Gbps target. This survey was carried out to monitor progress as part of the 2025 Gigabit Society objectives. Responses to the survey are a factor named '2025 100Mbps Target' in the model. Non-EU countries were not part of this survey, and are included in the 'No answer' group along with Romania and Slovakia. For full responses see Appendix 1.

At least 100 Mbps upgradable to 1 Gbps coverage for all citizens?

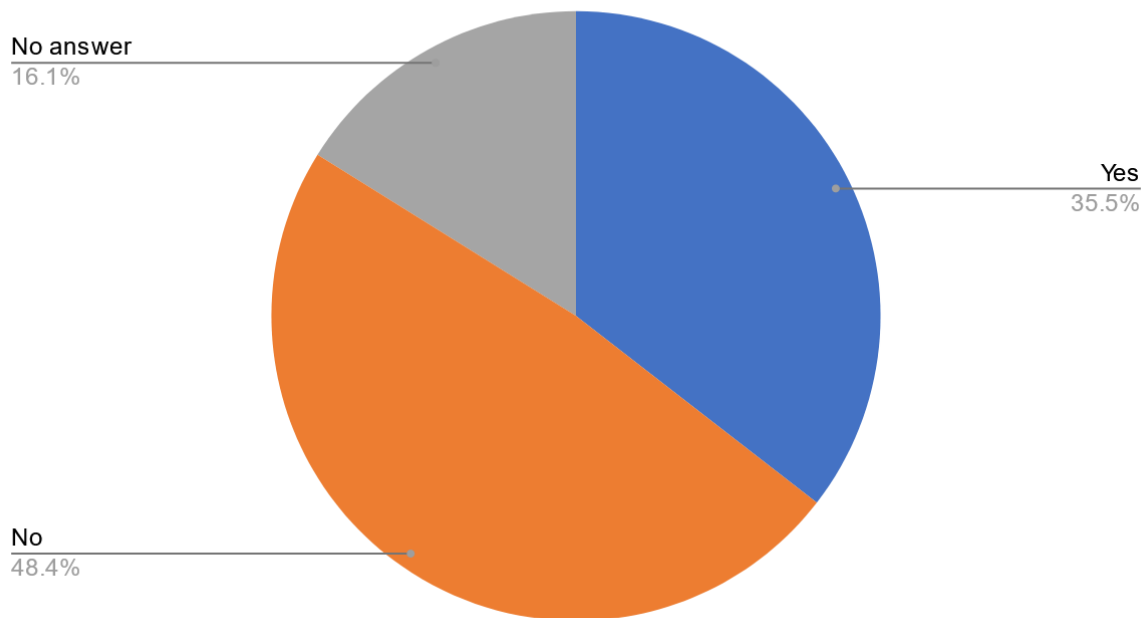


Figure 7: 2025 Gigabit Society Survey of NBPs Goal on Reaching 100Mbps upgradable to 1Gbps coverage for all citizens by 2025 (List of responses by country in Appendix 1)

The Role of Cable/DOCSIS 3/4 to 2030

Although most stakeholders consider FTTP to be the future-proof technology of choice for both policy support and private investment, cable continues to play a significant role and will continue to remain relevant for at least the next decade, in countries with a significant established cable infrastructure. Germany is one such country, which due to large prior investment has cable coverage far surpassing that of fibre. Some operators, like Virgin Media O2 in the UK, are also heavily invested in the technology, and with recent upgrades to the DOCSIS 3.1 protocol the ability of cable to serve gigabit (and multi-gig) connectivity is in place.

While there are significant existing networks of co-ax cable across Europe there is no significant additional deployment today. All the operators who are expanding are deploying (or upgrading to) fibre, even though they still run the DOCSIS technologies (via RFoG) over the top. DOCSIS3.1 does not meet the same performance standards as XGPON, for example, but there will be a further upgrade to DOCSIS 4 later in the decade which will close

the gap. Looking at a graph of the footprint of the cable network in Europe from 2016 to 2021, we see coverage slightly above 50% with only very minor overall expansion.

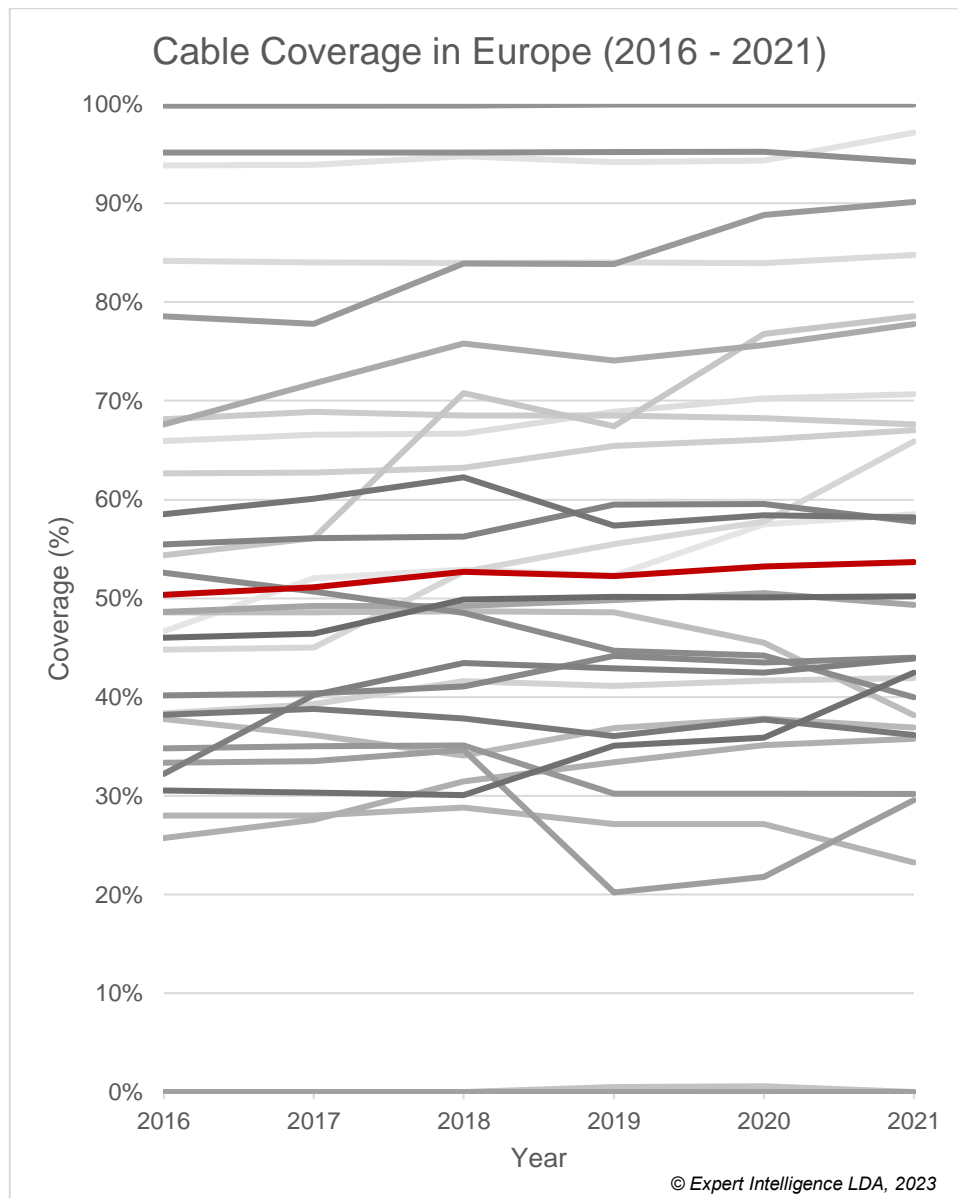


Figure 8: Cable coverage across European countries and European average (red) - 2016 to 2021.

Population Data

The population data layer at the kilometre-grid level was developed by Point Topic and Expert Intelligence, which in turn are originally based on kilometre-grid data published by the European Commission's Copernicus Programme, CORINE, and others. 2021 populations were used to aggregate broadband coverage from years after 2021. As we did not forecast population figures to 2030 at the kilometre-grid level, therefore any relative change in population densities between 2021 and 2030 are not considered.

Current State and Potential Opportunities for the Satellite Broadband Market

Satellite ‘broadband’ in some form has been in existence for the last few decades, it has until recently not been able to compete widely with fixed broadband technology due to high costs and low bandwidth, in part due to relying on traditional geosynchronous satellites orbiting Earth at great distances.

Low Earth Orbit (LEO) satellite constellations, like Starlink, are changing this. Starlink is the first such operator with mass-market appeal, with OneWeb and Project Kuiper (Amazon) the main competitors in the launch phase. In addition to these new entrants, traditional satellite communications operators, like Eutelsat and HughesNet, and governments (IRIS² and the Chinese StarNet) are currently planning to launch or facilitate LEO constellations.

Multiple competitors have licensed or are considering low-Earth-orbit constellations.

Nongeosynchronous-orbit constellations¹

| | Satellites | | Description | Status |
|--------------------------------|-----------------------|--------------|---|---|
| | Deployed ² | Planned | | |
| SpaceX Starlink | 2,373 | 9,553–41,943 | Satellites in low-Earth orbit (LEO) and very-low-Earth orbit (VLEO); Ka (4,500) and V (7,500) bands | Launched initial 2,000 satellites; building 150–250 more per month; ~500,000 active users; initial B2B agreements announced |
| OneWeb | 428 | 220–6,732 | Satellites in LEO; Ka and Ku bands | 1st-generation constellation of 648; launches resumed in 2020 but now on hold |
| Astra | N/A | 13,620 | Satellites in LEO; V band | Filed with US Federal Communications Commission (FCC) in Nov 2021 for 13,620 nongeostationary satellites |
| Amazon Project Kuiper | N/A | 3,236 | Satellites in LEO; Ka band | Approved by FCC; factory being built; announced contracts with various companies in Apr 2022 for initial deployment |
| Globalstar | N/A | 3,080 | Satellites in LEO | Filed with ITU ³ in Nov 2021; requested 100 orbital planes at heights of 485–700 km |
| Telesat | 1 | 188–1,672 | Satellites in LEO; Ka and potentially V bands | Approved by FCC; first launch planned for 2023 |
| HughesNet | N/A | 1,440 | Satellites in LEO; V band | Filed with FCC in Nov 2021 for 1,440 LEO satellites |
| Boeing | N/A | 147 | Satellites in LEO and high-elliptical orbit (HEO); V band | Revised original application with FCC in Nov 2021 for 132 LEO and 15 HEO satellites |
| Viasat | N/A | 288 | Satellites in LEO; Ka and V bands | Originally approved by FCC for 20 medium-Earth orbit (MEO) satellites; filed with FCC in May 2020 for 288 LEO satellites |
| Kepler Communications | 13 | 127–360 | Satellites in LEO; Ka and Ku bands | Filed with FCC in 2016 for 140 satellites; filed with FCC in May 2020 for 360 satellites; rideshares booked with multiple providers |
| SES | N/A | 36–70 | Satellites in LEO, MEO, and geostationary orbit; Ka band | O3b deployed; O3b mPOWER scheduled to begin launch in 2022; filed with FCC for 36 LEO satellites to provide high-speed Internet of Things service |
| China Satellite Communications | N/A | 12,996 | Satellites in LEO; V band | Filed spectrum application with ITU for 2 constellations; possible partnership for satellite launch |

¹As of Jun 9, 2022.
²Excludes inactive and deorbited satellites.
³International Telecommunication Union.

McKinsey & Company

Figure 9: Overview of deployed and planned commercial LEO constellations. [12]

While significant challenges (managing mega-constellations of never-seen-before scale, congestion, end-of-life satellites, geopolitics, risk of conflict) remain, the future is certain to see more involvement of big tech, terrestrial telecommunications companies and content providers. BT already has partnerships with OneWeb, Microsoft and Google with Starlink. OneWeb and Telesat confirmed that they will not provide direct sales to end-users [12] – they will however engage in B2B partnerships which may in the future involve established ISPs selling their bandwidth to end-users in areas without fixed broadband footprint.

While we project the scale of the consumer broadband market that is not the only part that satellite plays in the networks of today and tomorrow. Other applications will continue being developed - mobile connectivity, IoT, drone, airplane and ship connectivity, emergency services, secure communications as well as defence. While the lines may become more blurred in the near future, the scope of the paper will need to be limited to services comparable to fixed broadband provision - those which are provided at a fixed location and used by consumers or businesses, at competitive prices, and generally without data caps.

GEO, MEO and LEO satellites are strategic necessities as well as commercial assets and the full range of options that mobile communications platforms present is a boost to any country, region or economy.

We will exclude the last generation of high-altitude, geosynchronous (GEO) satellites from our analysis (available through services like HughesNet and Freedomsat). In the context of satellite broadband for consumers/businesses, high-altitude geosynchronous (GEO) satellites will likely play a reduced role in Europe, even as they extend their reach in Africa. Muscled out by the sheer number of LEO satellites already able to provide bandwidth in Europe and with more on the way the GEO satellites are retasked.

Finally, while opportunity is ample, there will be a limit to how many subscribers even a fully deployed LEO satellite broadband constellation will be able to support, which may eventually put a hard cap on the potential market size, or see limited bandwidth directed away from the consumer market and towards higher paying clients like the military. We will return to this issue in a later section.

European Policy and the Satellite Market

European policymakers are busy finding new ways to strengthen their role in the satellites market through a coordinated European approach, so as not to lose out to a potentially US-dominated commercial market or fall behind the state-coordinated StarNet programme in China.

In 2022, the IRIS² programme was launched, aiming to foster cooperation between the many European space industry and telecoms companies and launch a European satellite mega-constellation with full service by 2027 IRIS² will provide mass-market broadband, to Europe as well as, due to the planned orbits of the satellites, to Africa and the Arctic.

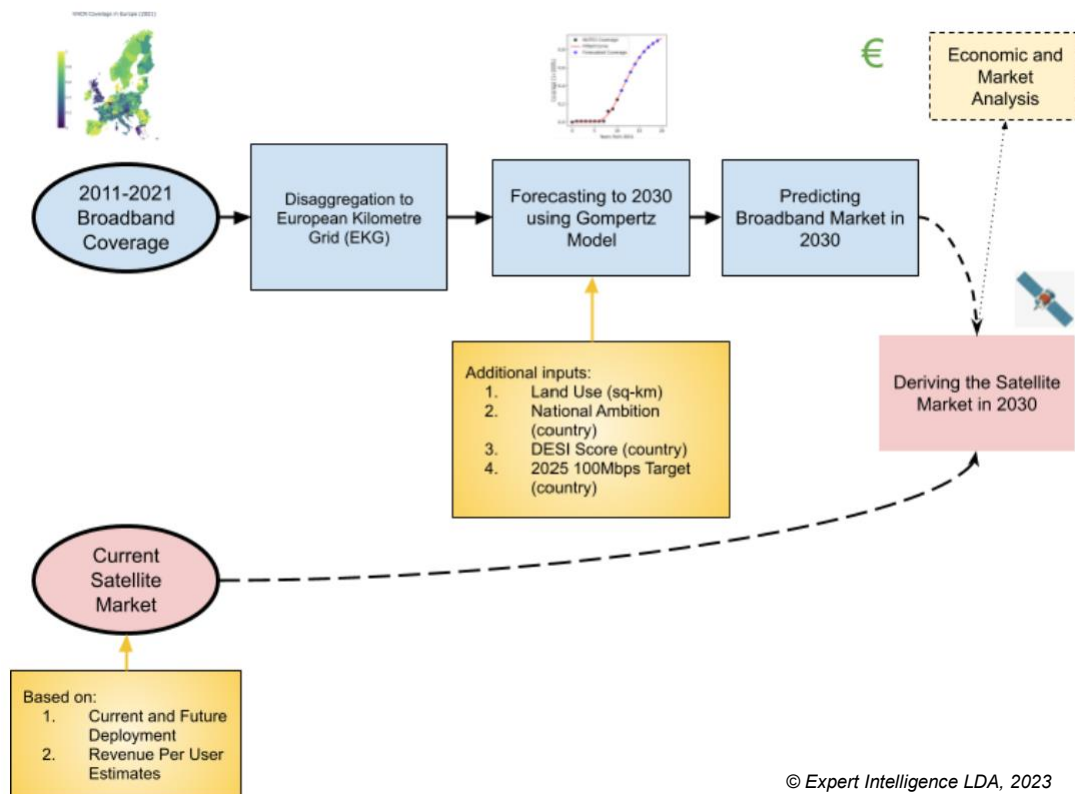
With the current level of investment and action, it is safe to assume that by 2030 Europeans will have reasonable options available to them for connecting to satellite-powered broadband in a cost-effective and reliable manner.

Modelling Approach

The following section will go over our modelling approach in more detail, including the choice of a Gompertz function to project growth, what factors were used to control growth as well as differences between the scenarios we ran.

Model Structure

A diagram representing the structure of our model is shown below:



© Expert Intelligence LDA, 2023

Figure 10: Model Overview

To predict the satellite broadband market in 2030, we forecast fixed broadband coverage to 2030 by using a logistic growth model based on the Gompertz function. This data is distributed from NUTS3-level down to square-kilometre level. Compared to a standard logistic growth model, the Gompertz function is asymmetric and growth (adoption) slows down as time progresses. It is widely applied in biology, for example to model tumour growth, and has also found wide use in predicting the propagation of technologies within society [13, 14] as it effectively captures the difficulty of ‘completing’ penetration against a diminishing but ever remaining proportion of society lacking adoption.

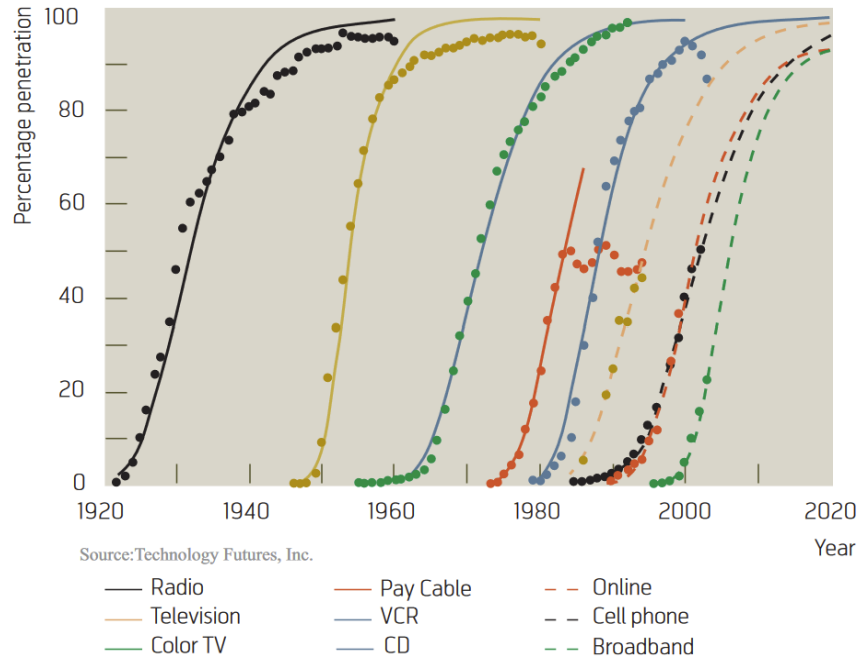


Figure 11: Penetration of different technologies in the US with Gompertz functions [14]

The Gompertz function is defined as

$$f(t) = ae^{-be^{-ct}}$$

where t = time, a = asymptote, b = displacement along x-axis, c = growth rate.

We assume an asymptote of 1 (100% coverage) throughout the model for FTTP coverage, while DOCSIS 3.1 coverage is capped at the 2021 extent of the cable network.

Figure 12 (below) shows how the Gompertz function is fit to 2011 - 2021 coverage on a 'best-fit' basis. 2011 to 2021 are shown as black points, to which the curve is fit. Coverage past 2021 ('Forecasted Coverage') can then be plotted against the curve of best fit.

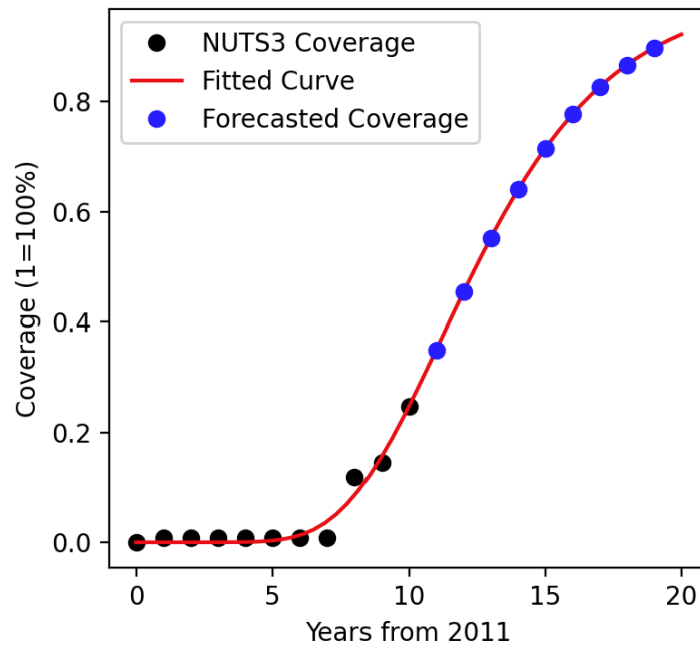


Figure 12: Gompertz Curve (red) with distributed NUTS3 coverage (black) and forecasted coverage (blue) by years from 2011

For square-kilometre cells unsuitable for the Gompertz function (usually where gradient is flat and coverage at close to 0% or 100%) we instead applied a linear regression. The Gompertz function was used 100% of the time for forecasting FTTP, and around 78% for forecasting DOCSIS 3.1 across all scenarios.

FTTP and DOCSIS 3.1 coverage are forecasted independently at the square-kilometre level. DOCSIS 3.1 coverage data is only available to us from 2019, thus to improve fit we assumed 0% DOCSIS 3.1 coverage in 2017 for all cells. DOCSIS 3.1 coverage is capped at the 2021 extent of the nation-wide cable network.

After forecasting, we then summed up FTTP and DOCSIS 3.1 coverage to get an estimate of overall VHCN coverage. To do this, we have had to assume a certain level of 'overbuild', i.e. a proportion of the population which is able to access both FTTP and DOCSIS 3.1 at the same time. With there being little data on this available, we assume an overbuild of 46% between DOCSIS 3.1 and FTTP across all regions covered by the model, a figure which is based on Point Topic data on FTTP/DOCSIS 3.1 overbuild within the UK. Although this number may vary substantially across other European countries, the assumption of both FTTP and DOCSIS 3.1 coverage having significant overbuild due to build concentrating in the most commercially viable spaces will hold true.

Factors

Coverage data was combined with land cover data from the Corine Land Cover [15] programme of the Copernicus Land Monitoring Service, as well as other factors (depending on scenarios). By now employing the Gompertz function, we adjust the gradient of growth with respect to the scenarios, and forecast each square-kilometre grid cell individually. This permits a granular projection with respect to current coverage, demographics, land use and other factors. The 'Scenarios' section details how factors influence modelling across different scenarios.

We use a number of factors to score the ambitions and expected pace of fixed broadband improvements of European countries. These factors are summarised in the table below.

| Factor | Classifications | Description |
|----------------------------|---|---|
| Land Use Factor | 1 = natural 2 = industrial 3 = urban/inhabited 4 = other | 2018 Corine Land Cover classifications, centroids per kilometre-grid square, grouped into natural/industrial/urban/other (see Appendix 2 for full classification) |
| National Ambition Factor | 1 = Highest 2 = High Average 3 = Low Average 4 = Lowest 5 = Greece Only | Summary of level of ambition of national plans and investments into fixed broadband infrastructure (see Appendix 3 for full classification) |
| DESI Factor | 1 = High 2 = Medium 3 = Low | Countries as classified by 2022 European Commission Digital Economy and Society Index (DESI) scores, excluding the 'Connectivity' component. Grouped into above, within, below 1 standard deviation from average (see Appendix 4 for full classification) |
| 2025 100Mbps Target Factor | 1 = Respond 'Yes' 2 = No response 3 = Respond 'No' | EU Member States' responses to whether National Broadband Plans refer to the below target: "Q.3.3. At least 100 Mbps upgradable to 1 Gbps coverage for all citizens?" Non-EU members were grouped as 'No response' (see Appendix 1 for full classification) |

Table 1: Model Factors and Descriptions

The factors will directly control the gradient at which kilometre-square coverage grows, by scaling the difference between 2021 coverage and forecasted coverage through multiplication by the factors. Factors are chained, so that two factors of 0.8 applied to the same forecasted square-kilometre grid cell will result in an overall factor of $0.8 * 0.8 = 0.64$. An example how this affects forecasts is shown below.

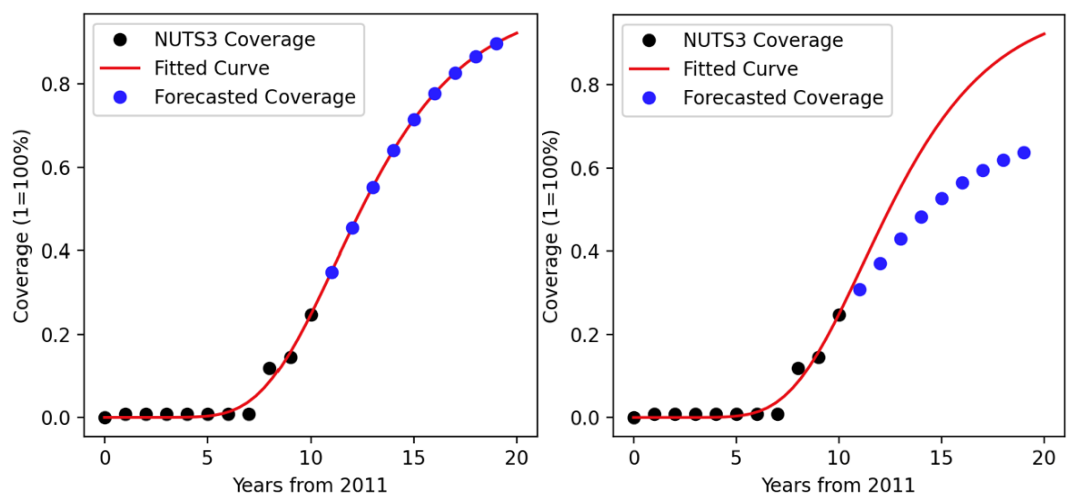


Figure 13: Example of forecasted FTTP coverage at square-kilometre level, left: without additional factors; right: with additional factors

Scenarios

Based on the inputs described above, a number of scenarios were run with different parameters:

Scenario 1 (Baseline Scenario): based on a combination of land use classification ('Land Use'), as well as national fixed rollout ambition ('National Ambition'). This is our baseline scenario as it makes adjustments to projected coverage based on land use and some weighing based on national differences.

Scenario 2 (Constrained Rollout Scenario): Rollout is additionally controlled by the DESI index score ('DESI Score') as well as the self-reported 2025 National Broadband Plan target of reaching 100Mbps coverage for all citizens (where possible responses were 'Yes' and 'No'). Similar to Scenario 1, but predicts more divergent trajectories for countries based on current and expected performance.

Scenario 3 (No Factor Scenario): Broadband coverage is projected only based on current growth trajectory, without introducing additional factors. No additional factors or constraints.

The interaction between scenarios and factors is shown in the table below:

| Model Factor | | Scenario 1 | | | | | Scenario 2 | | | | | Scenario 3 | | | | |
|---------------------|--------|------------|-----|-----|-----|-----|------------|-----|-----|-----|-----|------------|---|---|---|---|
| Land Use | Group | 1 | 2 | 3 | 4 | | 1 | 2 | 3 | 4 | | 1 | 2 | 3 | 4 | |
| | Factor | 0.6 | 0.8 | 1 | 0 | | 0.6 | 0.8 | 1 | 0 | | 1 | 1 | 1 | 1 | |
| National Ambition | Group | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| | Factor | 1.0 | 0.9 | 0.8 | 0.7 | 0.6 | 1.0 | 0.9 | 0.8 | 0.7 | 0.6 | 1 | 1 | 1 | 1 | 1 |
| DESI Score | Group | | | | | | | 1 | 2 | 3 | | | | | | |
| | Factor | | | | | | | 1.1 | 1 | 0.9 | | | | | | |
| 2025 100Mbps Target | Group | | | | | | | 1 | 2 | 3 | | | | | | |
| | Factor | | | | | | | 1.1 | 1 | 0.9 | | | | | | |

Table 2: Model Factors: Groups and Factors

Aggregation from Square-kilometre grid to NUTS3

Following forecasting of coverage at kilometre-grid level, we aggregate data to NUTS3-level and country-level using 2021 population data as weights. The model does not account for any changes in relative population densities at the square-kilometre level between 2021 and 2030.

Model Results

Fixed Broadband Coverage for the year 2030 for all countries modelled is shown below, split out by technology groups covered (FTTP, DOCSIS 3.1, VHCN) and scenarios (Baseline, Constrained Rollout, No Factors). Across all scenarios, a large disparity in coverage between countries continues to exist to 2030. 12 countries are expected to reach close to or 100% VHCN coverage in 2030 according to the baseline scenario, while 5 countries are expected to remain below 80% coverage.

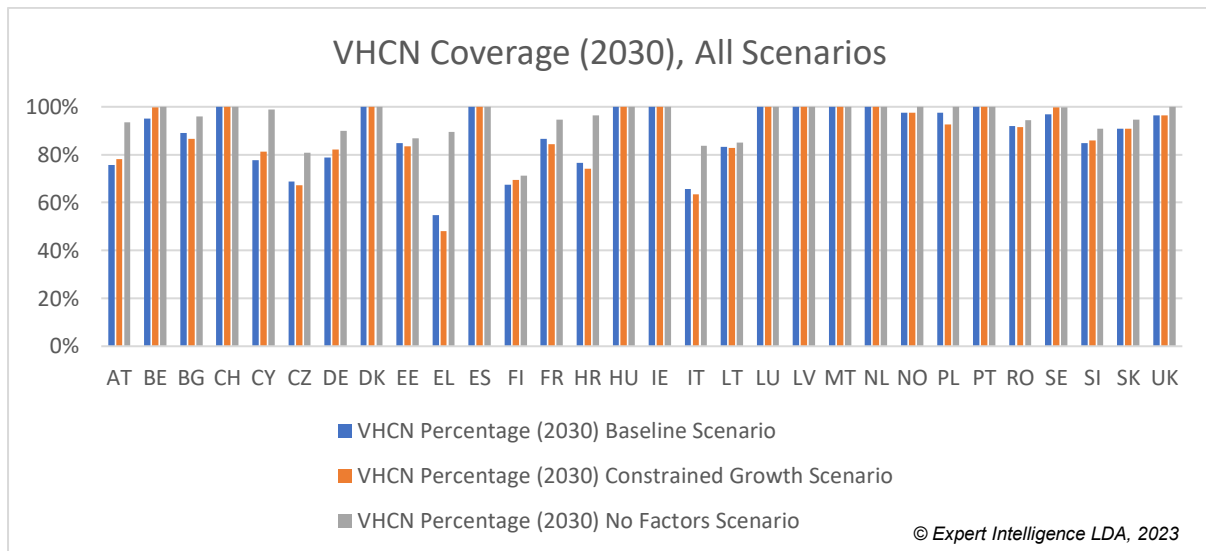


Figure 14: VHCN Coverage (2030): All Scenarios

2030 FTTP coverage shows that according to the current trajectories, all countries in Europe will be unable to reach 100% rollout. 7 countries will reach 90% coverage, while in 9 coverage remains below 70% according to the baseline scenario.

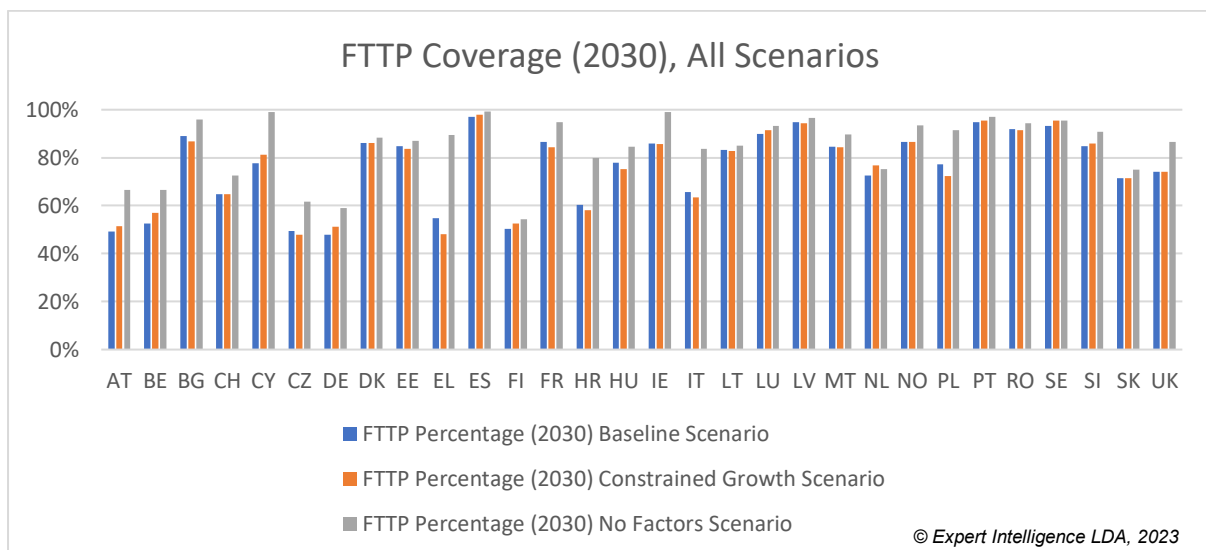


Figure 15: FTTP Coverage (2030): All Scenarios

For DOCSIS 3.1 coverage, we make the assumption that the overall cable network will not grow in footprint. Additionally, should a country or region have no existing DOCSIS

3.1 coverage by 2021 (as in France, for example), our model will not be able to predict when a potential rollout would begin and coverage will hence remain at zero.

As a result, 2030 coverage is mainly determined by the current 2021 footprint of the overall cable network, or is non-existent due to a lack of DOCSIS 3.1 footprint in 2011.

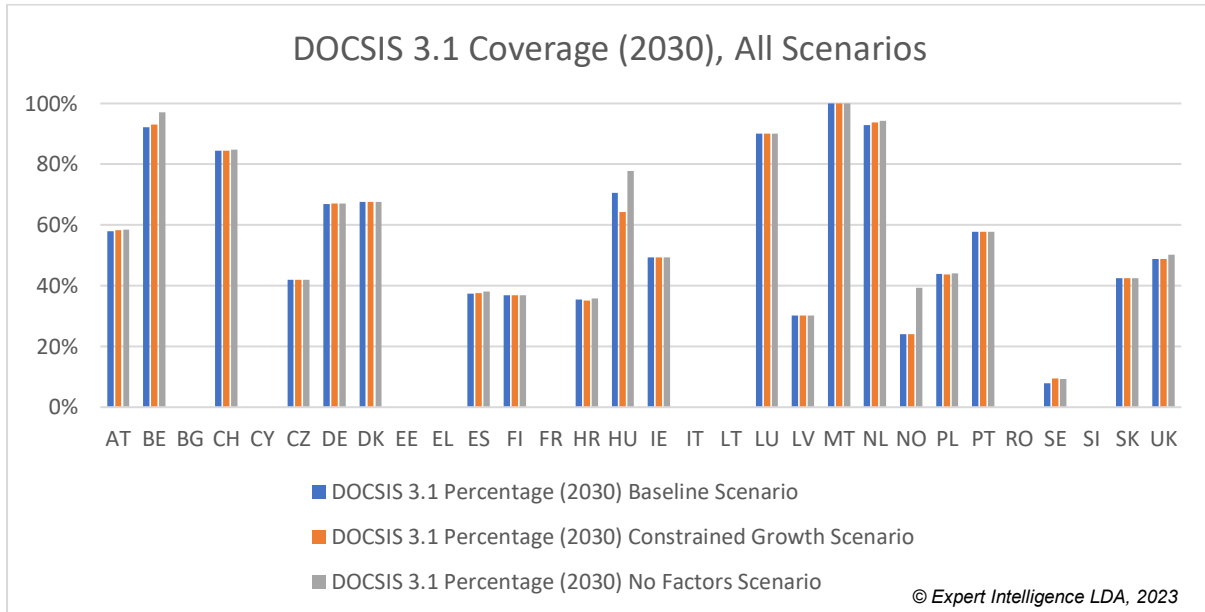
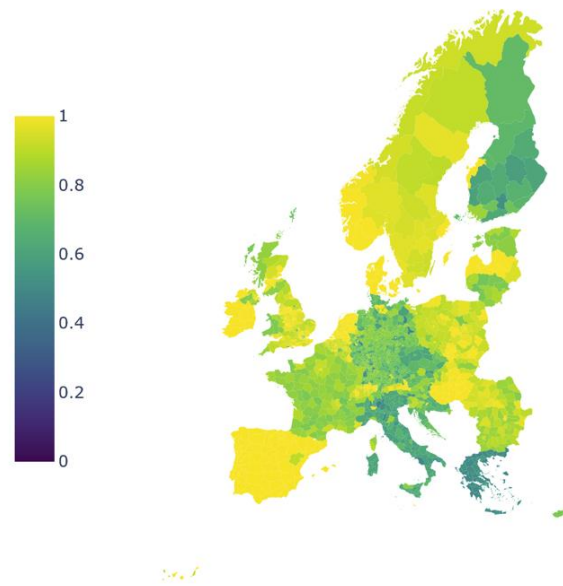


Figure 16: DOCSIS 3.1 Coverage (2030): All Scenarios

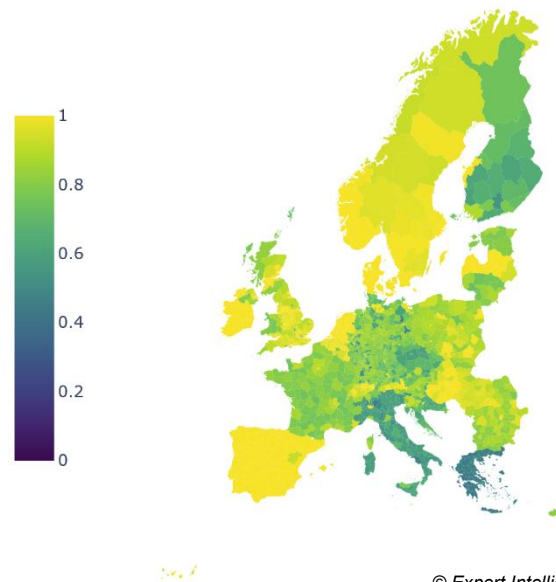
Mapping

Selected mapping of 2030 broadband coverage is shown below.



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Figure 17: VHCN Coverage (2030) - Scenario 1 (Baseline Scenario)



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Figure 18: VHCN Coverage (2030) - Scenario 2 (Constrained Rollout Scenario)

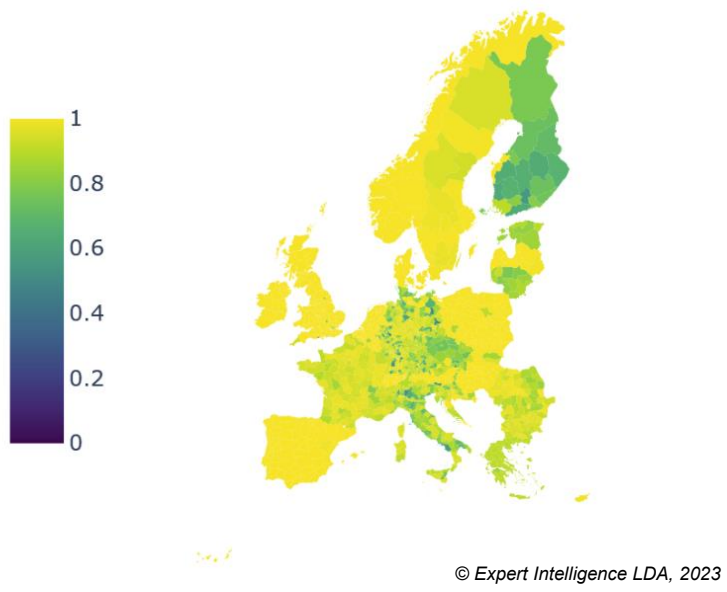


Figure 19: VHCN Coverage (2030) - Scenario 3 (No Factors Scenario)

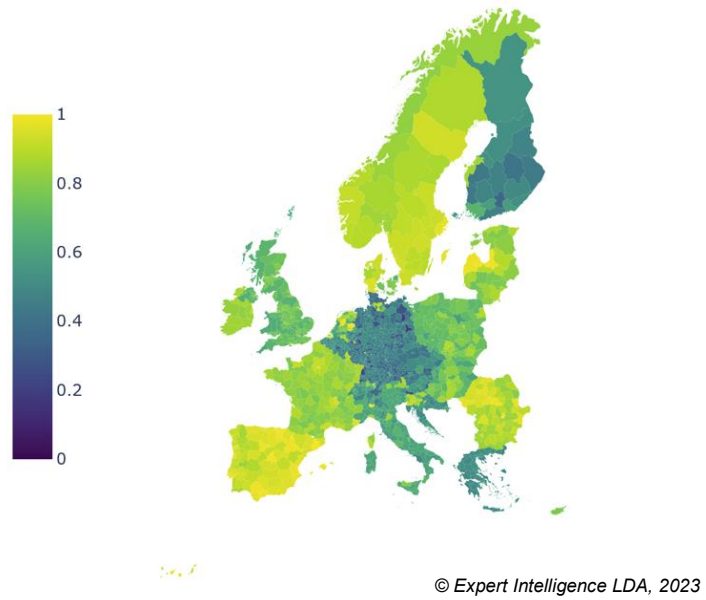


Figure 20: FTTP Coverage (2030) - Scenario 1 (Baseline Scenario)

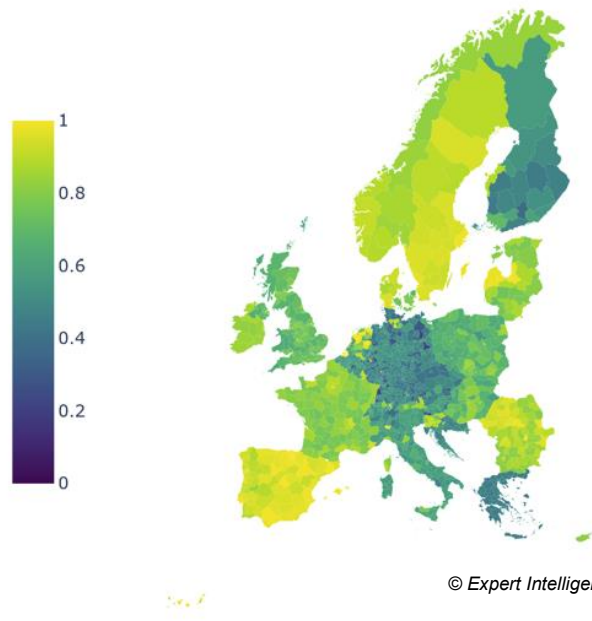


Figure 21: FTTP Coverage (2030) - Scenario 2 (Constrained Rollout Scenario)

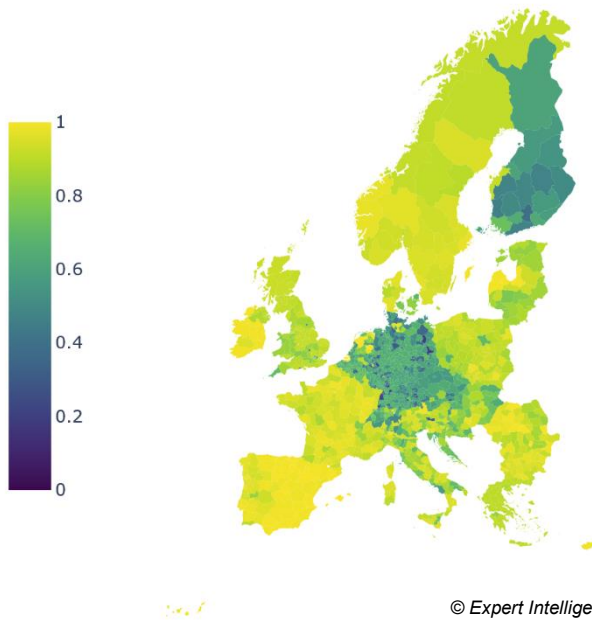


Figure 22: FTTP Coverage (2030) - Scenario 3 (No Factors Scenario)

The Satellite Broadband Market by 2030

Given the current launch plans of Starlink, OneWeb and IRIS² as well as the intentions of many LEO constellation operators to not directly sell to consumers, we expect that by 2030 consumers will have options from both companies offering direct services (Starlink) as well as traditional ISPs (T-Mobile, BT, etc.) or new entrants to provide internet to their homes and businesses at competitive prices.

Regional Analysis for the Satellite Market

From our forecasts, we can infer what areas in Europe will have the highest potential for the satellite industry. Although the scope of this project is limited to the provision of internet to as a consumer/business service comparable to terrestrial broadband, this holds true for related industries which depend on a high level of connectivity (logistics, smart agriculture, IoT and drones, backup connectivity applications).

Grouping EKGs by 2030 coverage allows us to highlight areas with low coverage as high potential areas. The assumption here is that high provision of fixed broadband coverage is inversely correlated with potential to the satellite industry. We use the below cut-off points to illustrate this. Note that areas classified as attractive may not necessarily represent a larger market in terms of customer base, as these areas may be rural and less populated. Starlink, for example, appears to be a popular service in urban areas across the US [16]. However, while one might think that this would unlock any large European urban area to become a thriving market for satellite broadband providers, there are clear limits to the subscriber density that a constellation like Starlink can support, even after full deployment [17, 18], which makes such a scenario unlikely.

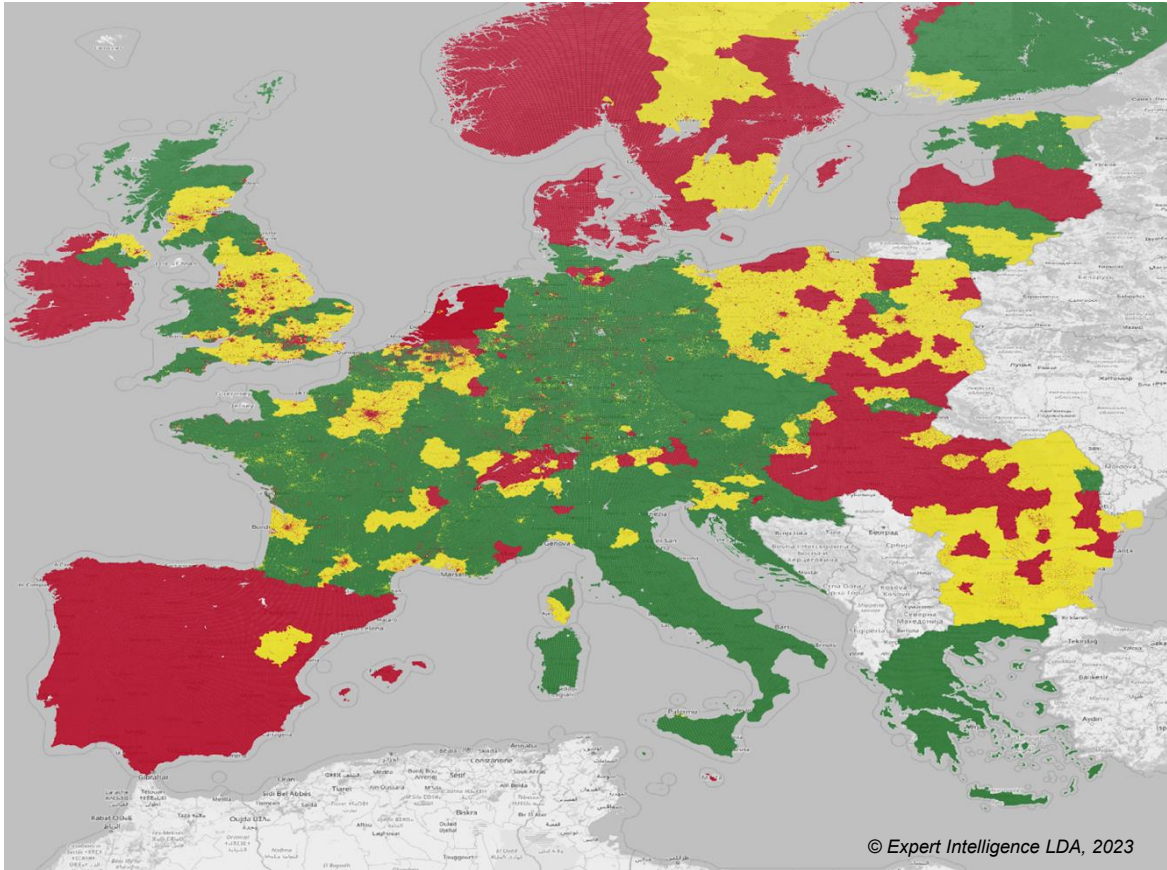


Figure 23: Attractivity to Satellite Services as Inverse of Fixed VHCN Coverage for Europe - Baseline Scenario

| Attractivity Map 1 – Connectivity Only | |
|--|-----------------|
| Coverage VHCN (2030) | Potential |
| >90% | Low (red) |
| 80% - 90% | Medium (yellow) |
| <80% | High (green) |

Apart from coverage of fixed services, another important consideration is the amount of disposable income available to consumers and businesses. Scoring countries by GDP/capita [19] relative to European average (a very basic analysis which could be greatly improved in the future) and weighing this equally to coverage shows a very different map:

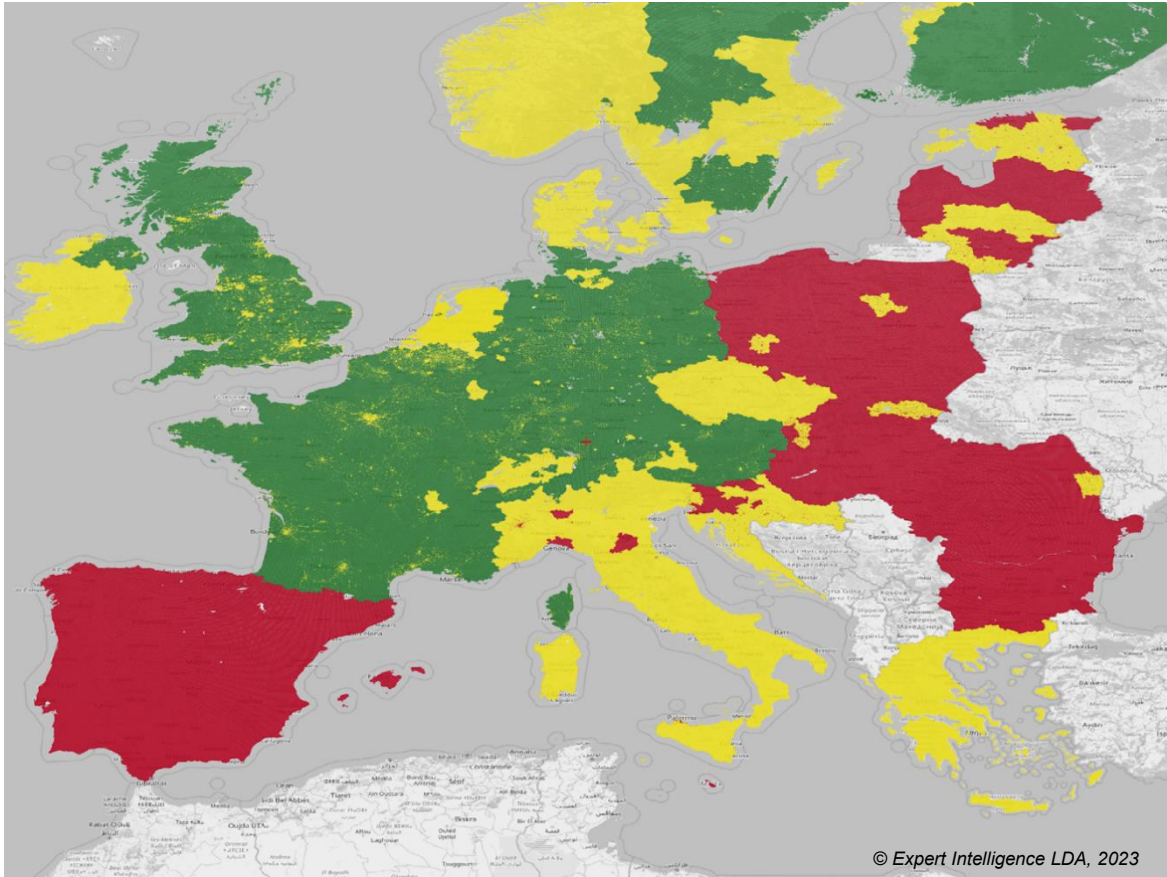


Figure 24: Attractivity to Satellite Services as Inverse of Fixed VHCN Coverage and GDP/capita for Europe - Baseline Scenario

| Attractivity Map 2 - Connectivity and Income | | |
|--|-----------------------------------|-----------------|
| Coverage VHCN (2030) | GDP/capita relative to EU average | Potential |
| >90% | below | Low (red) |
| | above | Medium (yellow) |
| 80% - 90% | below | Low (red) |
| | above | High (green) |
| <80% | below | Medium (yellow) |
| | above | High (green) |

Predicted Market Size

We can predict the market size for consumer satellite internet by taking the proportion of the population outside the fixed VHCN boundary in 2030. For example, should a square-kilometre cell in our model have a population of 100 and 90% VHCN coverage by 2030, we assume that 10% of this population (10 people) constitutes the market for satellite

internet. According to Scenario 1, this puts a total of 71 million⁶ Europeans outside the fixed VHCN boundary, or 13.6% of the population.

| | Scenario 1 | Scenario 2 | Scenario 3 |
|----------------|---|--------------|-------------|
| Country | Proportion of Population outside Fixed VHCN Boundary (2030) | | |
| EL | 45.3% | 51.9% | 10.6% |
| IT | 34.4% | 36.6% | 16.4% |
| FI | 32.7% | 30.7% | 29.1% |
| CZ | 31.2% | 32.8% | 19.1% |
| AT | 25.4% | 23.3% | 14.1% |
| HR | 24.4% | 26.5% | 6.6% |
| DE | 22.5% | 19.3% | 11.8% |
| CY | 22.4% | 18.7% | 1.0% |
| LT | 16.7% | 17.2% | 15.0% |
| EE | 15.3% | 16.4% | 13.1% |
| SI | 15.2% | 14.0% | 9.2% |
| FR | 13.4% | 15.7% | 5.3% |
| BG | 10.9% | 13.3% | 4.1% |
| SK | 9.3% | 9.3% | 6.8% |
| RO | 8.1% | 8.5% | 5.7% |
| BE | 5.3% | 2.0% | 0.4% |
| UK | 4.7% | 4.7% | 1.4% |
| CH | 4.4% | 4.4% | 1.3% |
| PL | 4.4% | 8.0% | 0.2% |
| SE | 3.5% | 1.1% | 0.9% |
| NO | 2.8% | 2.8% | 0.0% |
| NL | 0.7% | 0.4% | 0.5% |
| HU | 0.7% | 2.2% | 0.0% |
| LV | 0.6% | 0.8% | 0.1% |
| DK | 0.1% | 0.1% | 0.0% |
| ES | 0.1% | 0.1% | 0.0% |
| IE | 0.0% | 0.0% | 0.0% |
| LU | 0.0% | 0.0% | 0.0% |
| MT | 0.0% | 0.0% | 0.0% |
| PT | 0.0% | 0.0% | 0.0% |
| AVERAGE | 13.6% | 14.0% | 6.3% |

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Table 3: Proportion of Population outside Fixed VHCN Boundary in 2030

Should we now assume 2.2 members per household, a 30% take-up of satellite broadband services across this market, and a EUR 70 monthly fee multiplied by 12 months in a year, we estimate a market size of around EUR 3.8 to 8.4 billion for the satellite broadband market according to the Baseline Scenario, and EUR 8.3 billion according to the No Factors Scenario.

⁶ Based on 2021 populations and 2030 broadband coverage

| | Scenario 1 | Scenario 2 | Scenario 3 |
|--------------------|--|-------------------------|-------------------------|
| Country | Estimated Satellite Broadband Market Size (2030) | | |
| EL | € 1,837,200,000 | € 2,106,200,000 | € 430,200,000 |
| IT | € 7,803,400,000 | € 8,305,200,000 | € 3,716,000,000 |
| FI | € 685,200,000 | € 642,800,000 | € 609,500,000 |
| CZ | € 1,274,500,000 | € 1,338,400,000 | € 780,900,000 |
| AT | € 863,900,000 | € 790,900,000 | € 479,200,000 |
| HR | € 374,500,000 | € 407,600,000 | € 100,900,000 |
| DE | € 7,120,500,000 | € 6,127,300,000 | € 3,753,200,000 |
| CY | € 75,300,000 | € 63,100,000 | € 3,500,000 |
| LT | € 178,000,000 | € 183,600,000 | € 159,500,000 |
| EE | € 78,400,000 | € 84,100,000 | € 67,100,000 |
| SI | € 121,800,000 | € 112,200,000 | € 73,700,000 |
| FR | € 3,315,700,000 | € 3,889,800,000 | € 1,313,500,000 |
| BG | € 289,000,000 | € 352,900,000 | € 108,900,000 |
| SK | € 192,900,000 | € 192,900,000 | € 140,800,000 |
| RO | € 593,700,000 | € 624,000,000 | € 419,800,000 |
| BE | € 233,300,000 | € 86,500,000 | € 19,500,000 |
| UK | € 1,181,200,000 | € 1,181,200,000 | € 360,000,000 |
| CH | € 145,200,000 | € 145,200,000 | € 42,400,000 |
| PL | € 637,700,000 | € 1,158,700,000 | € 34,400,000 |
| SE | € 135,600,000 | € 42,300,000 | € 34,500,000 |
| NO | € 55,500,000 | € 55,500,000 | € 0 |
| NL | € 47,500,000 | € 23,700,000 | € 31,700,000 |
| HU | € 26,200,000 | € 83,300,000 | € 100,000 |
| LV | € 4,500,000 | € 5,600,000 | € 900,000 |
| DK | € 2,300,000 | € 2,500,000 | € 0 |
| ES | € 16,300,000 | € 12,700,000 | € 0 |
| IE | € 0 | € 0 | € 0 |
| LU | € 0 | € 0 | € 0 |
| MT | € 0 | € 0 | € 0 |
| PT | € 0 | € 0 | € 0 |
| TOTAL | € 27,289,300,000 | € 28,018,200,000 | € 12,680,200,000 |
| 30% Take-Up | € 8,186,790,000 | € 8,405,460,000 | € 3,804,060,000 |

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Table 4: Estimated Satellite Broadband Market Size (2030)

Note that population changes between 2021 and 2030 were not adjusted for in these forecasts. We sum up all populations within square-kilometre grid cells considered attractive as a proportion of country-total populations.

Limitations

The model will predict no or very low rollout if no or very low coverage is present by 2021. Any area with zero coverage of a certain technology until 2021 will continue having zero coverage, as the model is unable to estimate when an initial roll-out of a technology would begin. Hence, France continues to maintain zero DOCSIS 3.1 coverage until 2030, due to the absence of current roll-out. In reality, however, France currently has 23.1% of cable DOCSIS 3.0 coverage and it would be reasonable to assume that all of this would be upgraded to DOCSIS 3.1 by 2030.

As we continue to refine our modelling approach based on real-world data, it is important to acknowledge that our current factors were selected somewhat arbitrarily and could benefit from being replaced with more reliable and sourced data. However, it should be noted that obtaining such data can often be challenging. In order to enhance the accuracy of our analysis on satellite market size, future iterations of this model should give due consideration to the variations that exist across European countries across many of the dimensions we model, rather than relying solely on basic calculations. By incorporating a wider range of granular data and refining our data sources, especially square-kilometre granularity broadband data, further improvements would have been possible.

Conclusion

The authors have presented a model for forecasting FTTP and DOCSIS 3.1 coverage in Europe to 2030 through use of a Gompertz model, and using a number of factors including land use and national ambition to adjust growth. According to all 3 scenarios run, significant areas of Europe are expected to remain outside the fixed boundary for VHCN coverage in 2030. 33 to 71 million people, or 6.3% to 13.6% of Europe, are expected to not be connected to VHCN coverage in 2030. Considering the goals of the European Union's Digital Decade programme and the emergence of new satellite constellations, including the European Union's IRIS² programme, this represents a significant opportunity for satellite internet providers to fill the gap. We therefore estimate the size of the satellite internet market in Europe to be worth EUR 3.8 to 8.1 billion by 2030.

In summary, satellite broadband services hold the potential to provide a significant level of high-speed broadband availability in Europe, especially in areas where traditional fixed network technologies may not be feasible. By leveraging the advancements in satellite constellations, Europe can work towards achieving its objective of gigabit broadband for all.

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Geographic Boundary Files:

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Basemap:

Map data copyrighted OpenStreetMap contributors and available from <https://www.openstreetmap.org>

Appendices

Appendix 1: 2025 Gigabit Society Survey of NBPs Responses

| Country | Q.3.3. At least 100 Mbps upgradable to 1 Gbps coverage for all citizens? |
|----------------|--|
| Austria | Yes |
| Belgium | Yes |
| Bulgaria | No |
| Croatia | No |
| Cyprus | Yes |
| Czech Republic | No |
| Denmark | No |
| Estonia | No |
| Finland | Yes |
| France | No |
| Germany | Yes |
| Greece | No |
| Hungary | No |
| Ireland | No |
| Italy | No |
| Latvia | No |
| Lithuania | No |
| Luxembourg | Yes |
| Malta | No |
| Netherlands | Yes |
| Poland | No |
| Portugal | Yes |
| Romania | No answer |
| Slovakia | No answer |
| Slovenia | Yes |
| Spain | Yes |
| Sweden | Yes |
| UK | No |

Appendix 2: Classification of Corine Land Cover Classifications

| CLC_CODE | CLC_LABEL | Model Classification | Model Code |
|----------|---|----------------------|------------|
| 111 | continuous urban fabric | urban | 3 |
| 112 | discontinuous urban fabric | urban | 3 |
| 121 | industrial or commercial units | industrial | 2 |
| 122 | road and rail networks and associated land | industrial | 2 |
| 123 | port areas | industrial | 2 |
| 124 | airports | industrial | 2 |
| 131 | mineral extraction sites | industrial | 2 |
| 132 | dump sites | industrial | 2 |
| 133 | construction sites | industrial | 2 |
| 141 | green urban areas | urban | 3 |
| 142 | sport and leisure facilities | urban | 3 |
| 211 | non irrigated arable land | natural | 1 |
| 212 | permanently irrigated land | natural | 1 |
| 213 | rice fields | natural | 1 |
| 221 | vineyards | natural | 1 |
| 222 | fruit trees and berry plantations | natural | 1 |
| 223 | olive groves | natural | 1 |
| 231 | pastures | natural | 1 |
| 241 | annual crops associated with permanent crops | natural | 1 |
| 242 | complex cultivation patterns | natural | 1 |
| 243 | land principally occupied by agriculture with significant areas of natural vegetation | natural | 1 |
| 244 | agro forestry areas | natural | 1 |
| 311 | broad leaved forest | natural | 1 |
| 312 | coniferous forest | natural | 1 |

| | | | |
|-----|-----------------------------|---------|---|
| 313 | mixed forest | natural | 1 |
| 321 | natural grasslands | natural | 1 |
| 322 | moors and heathland | natural | 1 |
| 323 | sclerophyllous vegetation | natural | 1 |
| 324 | transitional woodland shrub | natural | 1 |
| 331 | beaches dunes sands | natural | 1 |
| 332 | bare rocks | natural | 1 |
| 333 | sparsely vegetated areas | natural | 1 |
| 334 | burnt areas | natural | 1 |
| 335 | glaciers and perpetual snow | natural | 1 |
| 411 | inland marshes | natural | 1 |
| 412 | peat bogs | natural | 1 |
| 421 | salt marshes | natural | 1 |
| 422 | salines | natural | 1 |
| 423 | intertidal flats | natural | 1 |
| 511 | water courses | natural | 1 |
| 512 | water bodies | natural | 1 |
| 521 | coastal lagoons | natural | 1 |
| 522 | estuaries | natural | 1 |
| 523 | sea and ocean | natural | 1 |
| 990 | unclassified land surface | none | 0 |
| 995 | unclassified water bodies | none | 0 |
| 999 | nodata | none | 0 |

Appendix 3: National Ambition by Country

| Country | Connectivity Toolbox Implementation (Scored)* | Group |
|----------------|---|-------|
| Malta | 26 | 1 |
| Denmark | 21.5 | 1 |
| Luxembourg | 15 | 1 |
| Spain | 20 | 1 |
| Bulgaria | 25 | 1 |
| Netherlands | 15.5 | 1 |
| Portugal | 15 | 1 |
| Latvia | 14.5 | 1 |
| Sweden | 21.5 | 1 |
| Estonia | 27 | 1 |
| Lithuania | 22 | 1 |
| Switzerland | 15 | 1 |
| Austria | 25.5 | 4 |
| Slovenia | 18 | 2 |
| Finland | 16 | 2 |
| Germany | 13.75 | 2 |
| Czech Republic | 17.25 | 4 |
| United Kingdom | 15 | 2 |
| Romania | 7.5 | 3 |
| Belgium | 14 | 2 |
| Croatia | 16 | 4 |
| Ireland | 6.5 | 3 |
| Greece | 10 | 5 |
| Italy | 14.5 | 4 |
| Slovakia | 13 | 2 |
| Cyprus | 14 | 4 |
| Norway | 10 | 3 |
| France | 12 | 2 |
| Hungary | 7 | 3 |
| Poland | 5 | 3 |

* Scored according to our own methodology and adjusted where deemed necessary

Appendix 4: DESI Ranking Groups

| Country | Overall Without Connectivity | Deviation from Average | Group (high = good) | Score Group |
|-----------------|------------------------------|------------------------|---------------------|-------------|
| Finland | 54.460625 | 16.05150926 | high | 1 |
| Denmark | 50.0615 | 11.65238426 | high | 1 |
| Netherlands | 49.84455 | 11.43543426 | high | 1 |
| Sweden | 50.159325 | 11.75020926 | high | 1 |
| Ireland | 47.35375 | 8.944634259 | high | 1 |
| Malta | 47.632475 | 9.223359259 | high | 1 |
| Spain | 43.345 | 4.935884259 | medium | 2 |
| Luxembourg | 44.025375 | 5.616259259 | medium | 2 |
| Estonia | 45.39985 | 6.990734259 | medium | 2 |
| Austria | 40.5593 | 2.150184259 | medium | 2 |
| Slovenia | 38.39595 | -0.01316574074 | medium | 2 |
| France | 37.2826 | -1.126515741 | medium | 2 |
| Germany | 36.05275 | -2.356365741 | medium | 2 |
| Lithuania | 40.376175 | 1.967059259 | medium | 2 |
| Portugal | 37.859875 | -0.5492407407 | medium | 2 |
| Belgium | 40.3507 | 1.941584259 | medium | 2 |
| Latvia | 37.1921 | -1.217015741 | medium | 2 |
| Italy | 33.947125 | -4.461990741 | medium | 2 |
| Czechia | 35.97105 | -2.438065741 | medium | 2 |
| Cyprus | 33.65815 | -4.750965741 | medium | 2 |
| Croatia | 35.53195 | -2.877165741 | medium | 2 |
| Hungary | 29.35855 | -9.050565741 | low | 3 |
| Slovakia | 30.9899 | -7.419215741 | medium | 2 |
| Poland | 28.918475 | -9.490640741 | low | 3 |
| Greece | 26.5365 | -11.87261574 | low | 3 |
| Bulgaria | 25.004125 | -13.40499074 | low | 3 |
| Romania | 16.7784 | -21.63071574 | low | 3 |
| United Kingdom* | | | | 2 |
| Switzerland* | | | | 2 |
| Norway* | | | | 2 |

* Non-EU countries were placed in the 'medium' category.