BOTTOM-UP LRIC MODEL SPECIFICATIONS

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Introduction

1.1 Context

In its 2025 decision[1] analysing the wholesale markets for local and central access, the Institut Luxembourgeois de Régulation (ILR) concluded that POST Luxembourg has significant market power (SMP) in both relevant wholesale markets.

The competition problem

There is a risk that, without regulation, POST could have both the incentive and ability to set and maintain excessively high wholesale prices and/or impose a price squeeze, ultimately harming end-users by weakening retail competition. The ILR therefore continues imposing the following obligations on POST to promote effective competition in the retail market: (i) access, (ii) non-discrimination, (iii) transparency, and (iv) price controls on wholesale access products. With regard to price controls, the ILR has decided to introduce price caps for wholesale access to fibre.

To underpin the imposition of price regulation on this market, ILR has engaged Frontier to update the existing cost model for the pricing of fibre unbundling.

1.2 Model objectives and outputs

In its tender document for this project, the ILR sets out that the objective of the cost model is to ensure its outputs can be used effectively to inform fibre unbundling price caps. It also states that the model should strike a balance between simplicity and robustness, and reflect realistic network deployment conditions to estimate the costs faced by a hypothetical efficient operator deploying a fibre local access network in Luxembourg.

To ensure the model is appropriately scoped and delivers outputs that serve ILR's regulatory goals, we consider it is important to first consider how its results are likely to be used by ILR. In particular, this requires assessing which price caps might be imposed on fibre local access products and whether the model would be relevant to inform the price caps.

1 Règlement ILR/T25/1 du 30 septembre 2025 portant sur la définition du marché pertinent de la fourniture en gros d'accès local en position déterminée (marché 1/2020), l'identification de l'opérateur puissant sur ce marché et les obligations lui imposées à ce titre, https://legilux.public.lu/eli/etat/leg/rilr/2025/09/30/a418/jo

Règlement ILR/T25/2 du 30 septembre 2025 portant sur la définition du marché pertinent de la fourniture en gros d'accès central en position déterminée pour produits de grande consommation (marché 3b/2014), l'identification de l'opérateur puissant sur ce marché et les obligations lui imposées à ce titre, https://legilux.public.lu/eli/etat/leg/rilr/2025/09/30/a419/jo

There are different approaches to setting price caps remedies. These include:

- **Cost-based prices:** setting price caps to bring price closer in line with costs. This can be done through bottom-up models, top-down models or benchmarking.
- **Pricing continuity:** applying price caps at the current price levels in real terms. This does not require a cost model.
- **Retail minus:** This does not require a cost model.

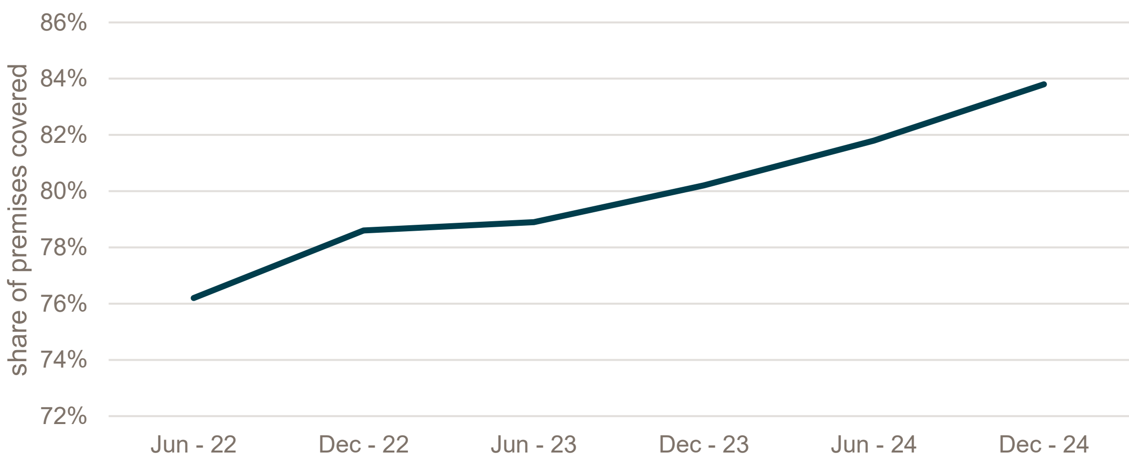
The bottom-up cost model would therefore only be used by ILR as a possible tool where cost-based pricing would be deemed necessary and where it can provide appropriate outputs.

In the subsections below, we recall the context of FTTH access products in Luxembourg, set out the objectives to consider when choosing the appropriate price cap approach, define the characteristics of the hypothetical efficient operator and assess which fibre local access products should be informed by the costs of that hypothetical efficient operator. In cases where the model does not product results, we also set out how the ILR may choose to deal with this.

1.2.1 Context

Luxembourg has made significant progress in the deployment of very high-capacity networks (VHCNs), with FTTH coverage reaching approximately 84% of premises by the end of 2024. This rollout has been driven almost exclusively by POST, which has publicly committed to achieving 100% FTTH coverage by 2030[2].

Figure 1 POST's FTTH coverage in Luxembourg



Source: ILR, Rapport statistique 2024

[2] Post Luxembourg annual report 2024, page 25

In terms of network architecture, the incumbent operator (POST) has deployed both P2MP and P2P fibre architectures, with P2P being largely predominant today. In February 2019, POST announced plans to gradually convert its existing P2MP infrastructure to P2P, further reinforcing the prominence of P2P in the national network. By the end of 2024, about 22% of all FTTH connections were built by using a P2MP topology.

However, taking into account the challenges of fibre deployment, POST has recently shifted its strategy by deploying the FTTH network using a P2MP topology in the remaining rural areas to be covered. This approach aims at achieving a 100% population coverage by 2030. Consequently, the proportion of connections using a P2MP topology is expected to increase again in the coming years.

1.2.2 Regulatory objectives

ILR's overarching goal as part of its design of remedies for wholesale fibre access products is to ensure fair market access to POST's fibre network and promote sustainable competition at the retail level to protect the interests of consumers. More specifically, when setting charge controls, ILR should aim to:

- Ensure that POST earns a reasonable and appropriate return on its past and future investments;
- Provide stable and predictable cost estimates to support long-term planning and regulatory certainty;
- Facilitate a practical and implementable framework that prioritises simplicity, transparency, and robustness.

Given the current competitive dynamics in Luxembourg, we consider that sending pricing signals to new market entrants is not a primary objective.

1.2.3 The characteristics of the hypothetical efficient operator (HEO)

A HEO is a notional construct used to estimate the costs of providing regulated wholesale services in a forward-looking manner. This operator does not reflect the specific operational or legacy characteristics of POST, but rather represents an efficient market participant deploying a modern network using current technologies, best practices, and efficient processes. The purpose of modelling such an operator is to establish cost estimates that reflect what an efficient provider would incur in supplying services under competitive conditions, thereby ensuring that regulated prices are fair, promote investment, and avoid entrenching inefficiencies that may exist in POST's legacy network.

Coverage and technology characteristics

In the context of Luxembourg, the efficient network architecture is a P2P fibre network. We therefore propose modelling the HEO as having 100% coverage using a P2P network. This modelling choice aligns well with regulatory objectives and Luxembourg's market dynamics for the next regulatory period (2026-2030), for several reasons:

- It **ensures a reasonable and appropriate return for POST**: By assuming full P2P deployment from the outset, the model reflects POST's stated ambition to achieve 100% P2P FTTH during the next regulatory period. This approach ensures that cost estimates are aligned with POST's actual investment trajectory and provides a fair basis for cost recovery, thereby preserving its incentives to complete the network rollout.

- It **delivers predictable and stable cost estimates**: Modelling a fully deployed mono-technology network avoids fluctuations in the cost base linked to ongoing rollouts or technology migration. This contributes to a stable and transparent regulatory framework, enabling long-term planning and price certainty for all market participants.

- It **facilitates a practical and implementable model**: Modelling network being gradually expanded would require assumptions on the pace and geography of deployment. These refinements would introduce significant complexity without materially improving the robustness of the results.

Demand characteristics

The HEO is assumed to serve demand equal to POST's total demand for residential broadband and business connectivity across all technologies (including copper, and P2MP fibre).

This modelling choice ensures that:

- The cost base of the HEO is dimensioned consistently with the actual scale of POST's customer base.

- The price derived from the model provides a robust and relevant benchmark for POST, as it reflects the costs an efficient operator of POST's scale would incur in supplying wholesale NGA products.

1.2.4 Assessment of charge control approaches for wholesale fibre access products

Passive Fibre Access on P2P network

This is the primary wholesale fibre access product used in Luxembourg, and it is expected to remain so throughout the next regulatory period.

We consider that a cost-based charge control would ensure that prices are aligned with the efficient costs of a P2P fibre network. We propose to estimate the cost-based charge, including appropriate capital recovery and a fair return on investment. This approach would directly support ILR's objectives to promote effective competition at the retail level, while ensuring POST can recover its justified investment. The cost-based charge can be directly estimated using the BULRIC cost model of the HEO in Luxembourg.

In contrast, a price continuity approach may not adequately ensure fair access for access seekers and protect consumers because it is unclear whether current price levels are cost-reflective.

VULA over a P2MP network

POST is obliged to provide VULA services over its P2MP architecture as a substitute for physical fibre unbundling access. Since 2020, some access seekers have used VULA, especially in areas where fibre unbundling is not available. By the end of 2024, 11% of all requested accesses were VULA. As the proportion of P2MP connections is expected to increase again in the coming years, a further increase in the share of VULA is still expected (see subsection 1.2.1. for further details).

Given their relatively limited footprint, we do not consider it proportionate to develop a cost model of P2MP network providing VULA services. Instead, VULA prices could be set by reference to the modelled P2P passive access prices, with appropriate adjustments to reflect both the lower technical capabilities of P2MP networks and the cost differences between active and passive services.

Ancillary Services

Ancillary services such as colocation, tie cables or electricity power consumption support the provision of wholesale fibre access services. We are not aware of any NRA that has modelled ancillary services on a bottom-up basis. Therefore, we recommend excluding these services from the cost model and suggest that the ILR rely instead on top-down cost information from POST to inform potential price caps.

1.3 Model scope

In line with ILR's methodological requirements, the cost model estimates the costs of deploying and operating a fibre-based local access network in Luxembourg for a HEO, relies on a "scorched node" approach and focuses exclusively on the access segments.

1.3.1 Modelling Approach

The "scorched node" approach reflects the actual locations of existing and planned Points of Presence (PoPs) and Distribution Points (DPs) in Luxembourg. This allows the model to preserve "real life" network concentration points while enabling the construction of a theoretically efficient network around them.

The model reflects the geographic characteristics of Luxembourg, including the location of residential and business premises and the presence of roads, along which the network of the HEO can be deployed.

1.3.2 Network Segments Modelled

The model individually identifies and costs the following segments of the optical local loop:

- **The feeder segment:** fibre links and infrastructure connecting PoPs to distribution points;
- **The distribution segment:** fibre links and infrastructure connecting distribution points to flexibility points (closest point of the road network to serve each building);
- **The drop segment:** fibre links and infrastructure connecting flexibility points to the network termination point (NTP) (i.e., the first distribution box within the building, but not including in-building cabling).

1.3.3 Treatment of inflation

The model is designed to calculate the unit cost of a Passive Fibre Access product over the next regulatory period in real terms, i.e. based on 2025 prices. This means that the outputs exclude the effect of general inflation.

To obtain forecasts of nominal costs for future years, inflation is added to the real unit cost, assuming it aligns with ECB's target (i.e. 2%)[3].

[3] https://www.ecb.europa.eu/mopo/strategy/pricestab/html/index.en.html

1.4 Scope of this document

This document sets out the specification for the development of a BULRIC model of an efficient VHCN operator in Luxembourg. Specifically, it presents:

- Our overall approach;
- The calculation steps and inputs used for the network dimension module; and
- The calculation steps and inputs used for the costing module.

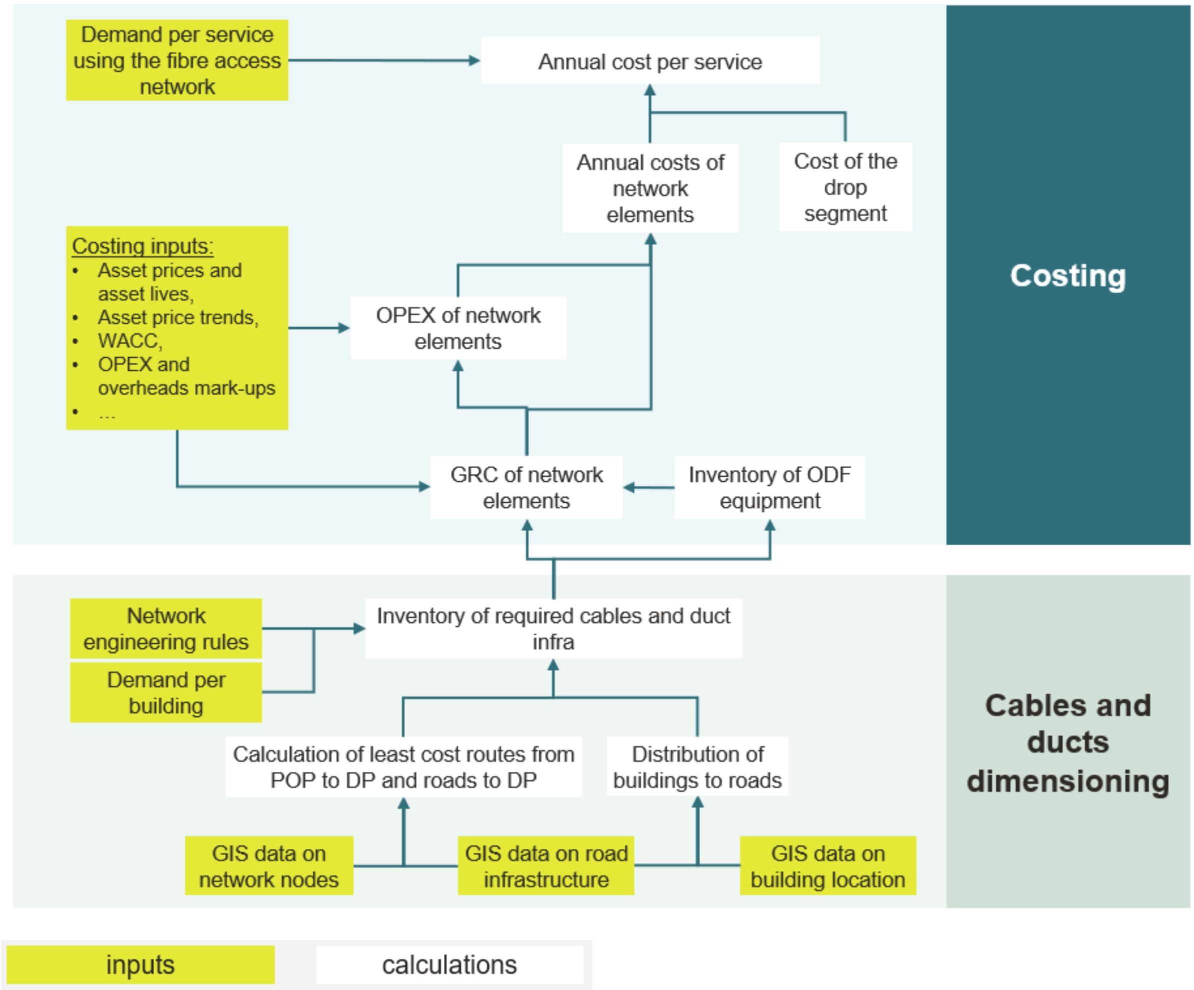
2 Bottom-up modelling approach

In this section, we set out the high-level structure of the model.

Our proposed approach builds on the overall structure of the 2013 model, with two main modules:

- A **Cables and ducts module**, which estimates the inventory of fibre cables, and physical infrastructure in the access network;
- A **Costing module**, which calculates the costs of the different elements used to provide wholesale access.

Figure 2 Overview of the module steps and inputs



Source: Frontier

Cables and ducts Module

This module is built using Python.

It starts from the location of residential and business premises in Luxembourg and builds a network between the PoPs and flexibility points. It is further explained in section 3.

Costing Module

This module is built using Excel.

It is based on the outputs of the *Cables and ducts module* and a set of other inputs to calculate annualised costs for the network and to derive the cost per service using the network. It is further explained in section 4.

3 Overview of calculation steps for the Cables and ducts module

In order to estimate the amount of duct and cable network required to meet potential levels of demand, this module performs a number of different calculations. These are summarised in the following subsections.

3.1 Step 1: GIS inputs

As explained in section 1.2.1, we rely on a scorched node approach using the location of POST's existing and future nodes in the access network.

The fibre network is assumed to follow public roads, represented in the Transport Network layer of the B-DL GeoBase. Because those roads are stored as MultiLineString geometries, we first disaggregate them into individual LineString segments and then extract the segment start- and end-points as unique GIS nodes.

The resulting road segment list ("lines") and node list form the graph on which every subsequent routing, duct-dimensioning and cable-sizing calculation is performed. In other words, this pre-processing converts the raw GIS layer into the two fundamental inputs – road segments and nodes – required by all downstream steps of the network-dimensioning module.

3.2 Step 2: Determining which subscribers are served by which nodes

3.2.1 Access network topology

The model connects customer premises to nodes through a multi-stage approach.

The model determines which subscribers are served by which nodes by:

- Defining road segments – i.e. sections of roads – based on the road network data;
- Using address data and road network data to determine which road segments have buildings (and therefore potential customer premises) adjacent to them and noting on which side of the road each building sits;
- Determining which road segments are served by each DP by minimising the distances between road-segments and DPs;
- Determining which DPs are served by each PoP site by minimising the distance between road DPs and PoPs.

3.2.2 Identifying road segments with buildings

The model determines which road segments have buildings on them and from which network routes need to be determined.

3.2.3 Assigning buildings to distribution points

The model attempts to minimise cable length and provide for an efficient distribution duct network connecting all the buildings to distribution points.

A mapping algorithm assigns every road network node, to the DP that is nearest to that node, where "nearest" is defined as the shortest path along the road network (rather than as the crow flies).

3.2.4 Assigning DPs to PoP sites

A similar approach to the one assigning building to distribution points is used to allocate DPs (and hence the customers served by the DPs) to PoP sites.

3.2.5 Access network routing

The model determines routes along which fibre cables run from end-user premises to PoP sites, via DPs. These routes are made up of three levels:

- Routes along the road segments where there are buildings;
- Routes from road segments to DPs; and
- Routes from each DP to its PoP site. These routes are used to determine both the cable requirements and the need for duct along routes (on road segments where no cables are routed there is no need for duct).

NB: The drop segment between the flexibility point and the NTP is generally built on a building-by-building basis when because it requires access to private grounds which need to be agreed with the building owner/developer. This compares to the roll-out for the rest of network which is deployed along public roads. We therefore assume that the drop segment is not built at the same time than the distribution segment and propose not to include it in the *Cables and ducts module*. We explain in section 4.1.1 how it is modelled.

3.3 Step 3: Cable dimensioning

3.3.1 Road segments with buildings

The size of the fibre cable along each side of the road is a function of (i) the number of potential end-users on that side of the road and (ii) the number of fibres per end-user. It is assumed that on at least one side of the road, the cable runs the length of the road. On the other side of the road, the length of cable and hence duct, may be shorter if there are few buildings on that side of the road.

Once the route of cables has been determined, the model then calculates the length and size of cables required to serve all potential customers.

3.3.2 Distribution network

The approach to cable dimensioning is based on a number of inputs:

- The number of potential customers located in each road segment;
- The routes from the road segment where potential customers are located to the DP, consisting in a list of the road segments between these two points; and
- The potential cable sizes available.

The model assumes that a single cable runs from each road segment where potential customers are located, to the DP along the route specified.

The size of fibre cable in the distribution network required to service each road segment with buildings is based on the number of fibres provided per potential customer.

The length of the fibre cable is then calculated based on the length of the route from the end of the road segment with buildings to the DP.

3.3.3 Feeder network

The approach in the feeder network is similar to that in the distribution network and is built up from the following information:

- The number of potential customers served per DP;
- The routes from DPs to the PoP sites; and
- The available cable sizes.

Fibre cables are installed along the routes from DP sites to PoP sites.

3.4 Step 4: Determining the duct network

Using the length and size of cables required, the model then calculates the length and number of ducts and trenches required to carry these cables for distribution and feeder segments.

3.4.1 Duct network along roads

The largest element of cost in the access network is trenching costs needed to install ducts. The scope of the duct network, i.e. those roads down which trench must be installed, is defined as those road segments which either:

- Have occupied buildings along them; or
- Are used for cables in the distribution and feeder network.

There is clearly a high degree of overlap between these two categories, with in many cases cables being routed down roads along which there are buildings.

Where there are buildings on both sides of a road segment, a duct is assumed to be built on both sides (although on the secondary side the length of duct may be shorter than the full length of the road segment). For road segments where there are only buildings on one side, or where there are no buildings (but cable is installed), duct is assumed to be built on one side only.

3.4.2 Number of ducts

The number of ducts required along the roads, is based on the total cross-sectional area of cables in each segment.

3.5 Outputs of the access network module

The main output of the above modelling is an inventory of the total assets required in the distribution and feeder segments:

- Length of cables by size (number of fibres);
- Number of kilometres of duct;
- Number of kilometres of trench required to install ducts.

4 The costing module

4.1 Network costing

The costing of network elements consists of the following steps:

- Estimation of costs of the drop segment;
- Estimation of the ODF costs;
- Calculation of Gross Replacement Costs (GRC) of network elements;
- Calculation of network design and planning costs;
- Annualising network costs;
- Calculating annual direct operational expenditure;
- Calculating total network costs.

4.1.1 Estimation of costs of the drop segment

The drop segment refers to the portion of the access network that connects the flexibility point to the NTP at the end-user premises. We understand that the location of the NTP in Luxembourg varies depending on the type of end-user premises[4]:

- For multi-dwelling units (MDUs), the NTP is typically a distribution box located inside the basement or ground floor of the building, where the final drop fibre cable terminates.
- For single-unit dwellings (SDUs), the NTP is a distribution box located within the customer's premises.

We also understand that the in-building wiring is built by the retail operator and is thus not part of the drop segment to be recovered by POST.

We consider that the cost components for the installation of the drop segment are broadly similar for MDUs and SDUs. These would include:

- Duct infrastructure costs;
- Labour costs;
- Material and transport costs.

In the following subsections, we describe how each of these installation cost elements can be estimated.

[4] POST's Reference Unbundling Offer, para 2.4.2

Duct infrastructure costs

We assume that duct infrastructure costs for the drop segment are incurred by the building owners or developers and should thus not be recovered by POST.

Labour costs

Labour costs for the construction of the final drop can be estimated by multiplying the average time required per intervention by the hourly labour cost of a technician.

We assume that one field technician is sufficient to complete the installation and that the time required to complete a final drop installation may be slightly longer for a MDU compared to a SDU, due to the larger number of fibres.

The technician's hourly rate should reflect the gross wage, plus a markup to cover indirect costs such as supervision and administrative overhead, insurance, training, and certification costs.

Material and transport costs

This category includes fibre cable, tools, clips and wall mounts used to secure the fibre cable and costs of the vehicle used to reach installation sites.

4.1.2 Estimation of ODF costs

ODFs are needed at each POP to allow for patching of all fibre lines installed at corresponding customer premises.

The corresponding costs include

- **the ODF hardware:** the number of ODF required to serve demand is estimated by dividing the number of fibre lines connected at each ODF by the utilisation factor of an ODF and the size (number of fibre connectors) of an ODF;
- **the space used by the ODF:** this is based on the space occupied by an ODF, the price per square meter of space and the number of ODFs.

4.1.3 Calculation of GRC of network elements

There are two main steps to estimate the total capital expenditure of the network modelled.

First, the unit cost of every network element is calculated for each year. This unit cost is based on the current (2025) price adjusted by forecast asset price trends. The unit cost includes both installation and asset costs. This is based on forward-looking costs based on current price data from stakeholders, forecast trends and benchmarks. Where list prices are used, these should reflect any discounts available to operators in Luxembourg.

Second, the unit cost is then multiplied by the volume of equipment required.

4.1.4 Calculation of network design and planning costs

Design and planning costs are modelled as investment costs and determined as a percentage mark-up of the amount of network investments.

4.1.5 Annualisation of costs

The model reflects how an efficient operator would recover the cost of capital investments over the useful lifetime of the assets. This is not necessarily equivalent to the asset life used for statutory accounting purposes since these tend to be quite conservative and do not necessarily reflect how long assets are actually in service for. Economic asset lives take account of the rapid development of technology in the industry and how assets are often replaced as new technology becomes available while the asset is still technically usable. The model reflects how asset lives vary across different categories of assets.

Annualised capital costs also include a return on capital employed equal to the cost of capital. The cost of capital is the minimum rate of return necessary to attract capital to an investment (i.e. just sufficient to compensate investors for the opportunity cost of investing, this is also known as an “economic profit”). This makes it the appropriate level of profit to allow on regulated assets. The cost of capital is typically measured using the weighted average cost of capital (WACC).

As a base case, we follow a tilted annuity approach as this gives constant allowable revenues in real terms. The tilt in the annuity formula takes account of how input costs change over time and therefore how costs would be recovered in a competitive market. In particular, where asset prices are increasing (decreasing) over time, an operator would tend to front load (back load) its cost recovery as entry to the market by another operator becomes less (more) costly.

Using a tilted annuity approach helps to avoid accounting distortions and better reflects the recoverability of costs compared to accounting forms of depreciation (i.e. straight-line depreciation). Another advantage is that the annual charge does not depend on the age of the asset. This means that the fact that the bottom-up model includes new assets is less of an issue. Long term asset price trends for different categories of assets are an input to the tilted annuity formula when calculating annualised network costs.

4.1.6 Annual direct operational expenditure

Annual direct operational expenditure relates to the on-going costs of running the network. This includes on-going staff and non-staff related costs. Direct operating costs are estimated as a percentage mark-up over GRC or on a per line basis. While it is theoretically possible to estimate operating costs using a bottom-up approach (e.g. estimating the hours required to perform various activities and then estimating the cost per hour of different types of labour), this does not necessarily lead to more robust results in practice. This is because such an approach would require a large amount of data and subjective judgements about input assumptions.

4.1.7 Calculation of total costs

In addition to network-specific costs, the total cost of providing passive fibre access must also account for an appropriate allocation of common costs that support overall business operations. These include costs such as corporate overheads, human resources, finance and support systems and licence and regulatory fees. They relate both to capital and ongoing operating costs.

Including these cost elements ensures that the model reflects the full economic cost of providing the wholesale service and supports the recovery of efficient expenditures by the access provider.

4.2 Service costing

The model derives the unit cost per line by allocating the total costs of the access network across the active end-users served by the HEO. This is done by dividing the total annualised network costs by the forecast volume of active lines.

The HEO is assumed to provide two types of services:

- Residential broadband,
- Business connectivity.

Since these services rely on the same underlying access network elements (ducts, trenches, fibre cables, and optical distribution frames), we apply a uniform cost allocation across them.