Input data and intermediate calculations

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1 Introduction

This document forms part of the call for inputs by the Institut Luxembourgeois de Régulation (ILR) on the development of a bottom-up long run incremental cost model (BU-LRIC).

The purpose of this document is to:

- List the key input data and assumptions that are used in the model; and
- Describe the sensitivity analysis that has been conducted.

One of the main objectives of the document is to provide transparency over the model inputs, subject to confidentiality.

The purpose of the sensitivity analysis is to consider how the model results change when key inputs to the model are changed. This demonstrates to stakeholders that the model results respond to changes in input assumptions in a way that one would expect.

1.1 Model input data and assumptions

The ILR relied on information from a number of different sources in developing the model. These sources included:

- Information provided by stakeholders during the model workshop;
- Information provided by stakeholders in response to the data request issued by the ILR; and
- Publicly available and benchmark information.

In developing the model, the ILR used data and information that best reflects:

- The availability of information; and
- The underlying model principles and objectives (as set out in the Model Specification document).

As described in the specification document, the model forecasts the cost of an efficient network operator in Luxembourg. This means that in developing the model, the ILR considered data from a number of sources in order to reflect efficient operating assumptions as well as the specific operating conditions in Luxembourg. For example, the model relies on information provided by the stakeholders to estimate the level of demand that an efficient network operator would need to serve, as well as to estimate costs. It should be noted that there are certain aspects of EPT's network that would not be consistent with the principles defined in the model specification and the model does not aim to replicate EPT's network. Therefore, the model also uses international benchmark data on the characteristics of an IP-only network in terms of dimensioning and costs.

We also consider the sensitivity of the results to key input assumptions (see Sections 1.1.3 and 9 below).

1.1.1 Information provided by stakeholders

As part of the model development, the ILR sought views from relevant stakeholders on a number of key areas of the model. In particular, the ILR organised a workshop with interested stakeholders on:

- An overview of the modelling process in terms of envisaged timeline and stakeholder involvement; and
- A description of the modelling principles and proposed approach.

Table 1. Stakeholders taking part in the meeting on 28 November 2012

Cegecom S.A.	Orange Communications Luxembourg S.A.
Entreprise des postes et télécommunications (EPT)	Tango SA
Luxembourg Online S.A. (LOL)	Belgacom

The ILR organised a separate meeting with EPT to understand:

- EPT's network strategy (EPT's planned rolled out, choice of technology, position and quantity of points presence);
- The Luxembourg operating environment; and
- Availability and suitability of data to use in the model.

The ILR invited stakeholders to submit data on the areas summarised in the table below.

Table 2. Data requested from stakeholders

Category	Description
Demand	Traffic parameters, voice traffic and wholesale and retail lines
Access network	Duct and cables in the access network
Core network	TDM network, DSL network, fibre access network; aggregation network (metro Ethernet), soft switches and media gateways, IP network, DWDM network, points of interconnection, and fibre and duct in the core network
Points of presence	Location, type and number of lines served
Capital expenditure	GRC and asset lives of cables, trenches and bores, distribution frames (ODF and MDF), DSLAMs and MSANs, OLTs, Ethernet switches, routers, MGWs and softswitches, DNS and buildings Conditions of payment
Operating expenditure	Access network, core network, power and air-conditioning, interconnection specific costs, wholesale employees and conditions of payment
Other	Dimensioning and planning rules

This information request was sent to stakeholders on 26 November with a deadline for submission set at 18 January 2013. This deadline was extended to 8 February 2013 in response to requests from stakeholders. The ILR provided clarifications on the data requested to operators on 15 January 2013.

The ILR received responses from:

- LOL;
- Telecom Luxembourg;
- Orange Luxembourg;
- EPT;
- Cegecom; and
- Tango.

The ILR also sought clarifications from the stakeholders on the information submitted in order to ensure the correct interpretation and use of the information in the model. Recognising the importance of information from EPT, the ILR also continued its discussions with EPT until the end of May 2013.

Additionally, the ILR asked a new market entrant, Lux Connect, to provide some information on costs.

1.1.2 Publicly available and benchmark information

In addition to the information provided by stakeholders, the ILR also gathered the information outlined in the table below.

Table 3. Other data considered by the ILR in the model development

Category	Description
Cadastre data	Road network and junction data List of addresses and occupied premises
International benchmarks	Equipment characteristics and costs, dimensioning rules, operating expenditure, parameters for the weighted average cost of capital (WACC)

1.1.3 Sensitivity analysis

In order to test the robustness of the model, we have carried out a sensitivity analysis. That is, the model has been run under a number of alternative scenarios in order to see how sensitive the results are to variations in the input data and assumptions. Section 9 describes this in further detail.

1.2 Rest of this document

The rest of this document sets out:

- The input data and assumptions used in the BU-LRIC model (Sections 2- 8); and
- The sensitivity analysis conducted (Section 9).

2 Demand estimation

The demand estimation relies on input data and assumptions in three key areas. These are described in further detail in the rest of this section:

- Section 2.1 describes the input data and assumptions relating to fibre coverage;
- Section 2.2 describes in the input data and assumptions relating to the number of active lines; and
- Section 2.3 describes the input data and assumptions relating to the usage on a per subscriber basis.

2.1 Fibre coverage

In the modelled network, all standard broadband lines (less than 24 Mbps) are assumed to be provided over copper to MDF technology. All ultrafast broadband lines (over 50Mbps) are assumed to be provided over FTTH.

The rollout assumptions for superfast broadband lines (greater than 24 Mbps but less than 50 Mbps) are as set out in the table below.

Table 4. FTTH coverage (% of premises covered)

	2013	2014	2015	2016	2017
GPON coverage	25%	25%	25%	25%	25%
P2P coverage	15%	20%	25%	30%	35%
FTTH coverage (GPON + P2P)	**40%**	**45%**	**50%**	**55%**	**60%**

Source: Model assumption

The model assumes no growth in GPON coverage – i.e. GPON fibre architecture covers 25% of premises in all years. P2P coverage is assumed to increase by 5 percentage points per year, from 15% in 2013 to 35% in 2017. As a result, total FTTH coverage rises from 40% in 2013 to 60% by 2017.

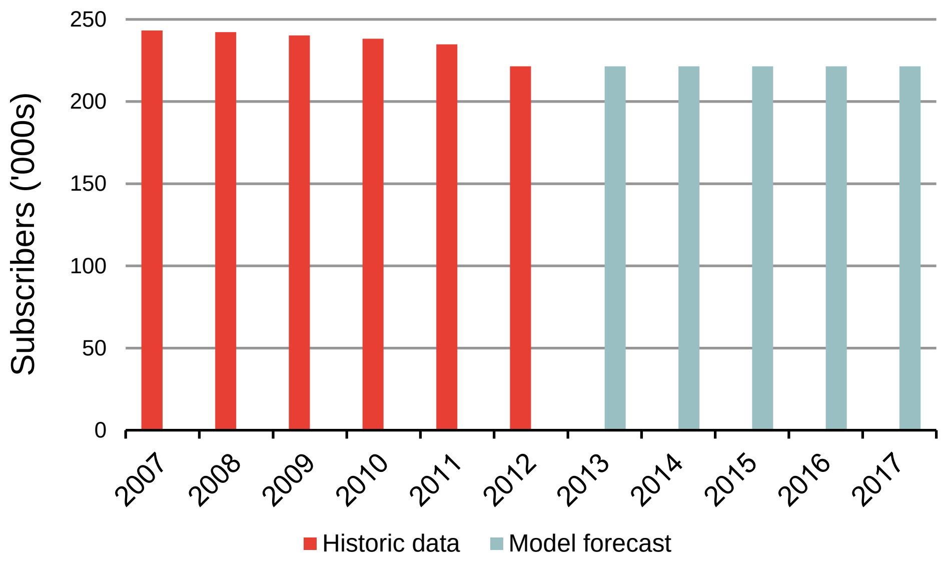
The coverage increase is modelled on an aggregate level rather than on individual addresses. The model assumes that the allocation of technologies is based on the number of households and businesses in the area around each distribution point.

2.2 Subscribers

2.2.1 Voice subscribers

The number of voice subscribers is forecast on a technology neutral basis. In other words, the forecast does not distinguish between subscribers who are served by different technologies - e.g. PSTN, ISDN and VOIP. The forecast is based on ILR data on the total number of voice subscribers in in Luxembourg 2012 (PSTN, ISDN 2 and ISDN 30). We assume that there is no growth or decline in the total number of voice subscribers over the period modelled. This is based on the assumption that there will continue to be demand for voice lines, as there is no evidence to support a growth or decline in recent trends. The figure below shows the historic data provided by stakeholders in the consultation process and the model forecast on the number of voice subscribers.

Figure 1. Voice subscribers



Source: Operators data based on ILR data request and model assumptions

We also assume that all broadband subscribers purchase voice services as broadband services cannot currently be purchased in Luxembourg without voice services.

2.2.2 Broadband subscribers

We assume the following number of year end broadband subscribers provided over different technologies.

Table 5. Year-end broadband subscribers (retail and wholesale)

	2013	2014	2015	2016	2017
Copper to MDF	111,139	101,132	90,045	78,764	66,318
FTTC	24,146	35,790	47,164	57,605	67,503
FTTH GPON	7,331	9,343	10,890	11,919	12,753
FTTH P2P	4,398	7,475	10,890	14,303	17,854
Total	**147,014**	**153,741**	**158,988**	**162,591**	**164,428**

Source: Model assumption

In the table we report our assumptions on the mixture of subscribers by speed.

The growth in subscribers is estimated to be 12% over the period modelled. This is based on recent international benchmark data and forecasts provided by the operators in Luxembourg. This corresponds to declining annual growth in broadband subscribers in each year modelled, also reflecting that the market is reaching full penetration.

Table 6. Percentage of broadband subscribers by speed (retail and wholesale)

	2013	2014	2015	2016	2017
Standard Broadband (<24 Mbps)	76%	66%	57%	48%	40%
Superfast Broadband (30 Mbps)	21%	30%	38%	45%	52%
Ultrafast Broadband (50+ Mbps)	3%	4%	6%	7%	8%

We assume that:

- All standard broadband subscribers are provided over copper to MDF; and
- All ultrafast broadband lines are provided over FTTH.

The table below sets out the take-up of superfast broadband split between subscribers served by FTTC technology and FTTH technology. This is based on the forecast of mix of VDSL and FTTH (GPON) 30 (retail and wholesale) provided by the operators.

Table 7. Take-up of superfast broadband by technology (retail and wholesale) - subscribers

	2013	2014	2015	2016	2017
FTTC	24,146	35,790	47,164	57,605	67,503
FTTH	7,013	10,027	12,964	15,594	18,274
Total	**31,159**	**45,817**	**60,128**	**73,199**	**85,777**

2.2.3 Corporate subscribers (leased lines)

The forecast number of corporate subscribers used in the model is mainly based on historic data (2011) and forecasts provided by the operators (2012-2016 inclusive). The number of subscribers in 2017 is forecast in the model to decrease by 1% for traditional leased lines (low and high speed) and to increase by 1% for Gigabit Ethernet. The table below shows the data used in the model.

Table 8. Corporate lines by speed

	2013	2014	2015	2016	2017
Low speed traditional (< 2Mbit/s)	3,099	2,956	2,850	2,766	2,738
High speed traditional (>= 2 Mbit/s)	5,612	5,526	5,460	5,407	5,354
Gigabit Ethernet	11,032	11,258	11,436	11,584	11,733
Total	**19,743**	**19,739**	**19,745**	**19,756**	**19,825**

In terms of distribution by access technology the forecast assumes that:

- All low speed traditional leased lines are provided over copper to MDF;
- All high speed traditional leased lines are provided over FTTC; and
- All gigabit Ethernet lines are provided by FTTH P2P.

This leads to the following distribution of subscribers across technologies.

Table 9. Corporate subscribers by access technology (end of year)

	2013	2014	2015	2016	2017
Copper to MDF	3,099	2,956	2,850	2,766	2,738
FTTC	5,612	5,526	5,460	5,407	5,354
FTTH – GPON	0	0	0	0	0
FTTH - P2P	11,032	11,258	11,436	11,584	11,733
Total	**19,743**	**19,739**	**19,745**	**19,756**	**19,825**

The model assumes that no corporate subscribers are served by GPON-fibre architecture. The underlying assumption is that all FTTH connections are P2P fibre for corporate subscribers. This is because under GPON fibre architecture, subscribers' traffic is carried over a shared fibre cable which may not provide sufficient quality of service for corporate traffic compared to P2P fibre.

2.3 Usage per subscriber

2.3.1 Voice traffic

We assume a 6% decline each year in voice traffic per subscriber per year based on the operators' responses to the ILR's data request for the period 2008 to 2011.

Table 10. Voice traffic per subscriber per year (minutes)

	2013	2014	2015	2016	2017
Onnet to geographic	1,561	1,462	1,369	1,282	1,201
Onnet other	35	33	31	29	27
Offnet	1,230	1,152	1,079	1,010	946
Call origination	274	257	241	225	211
Call termination	1,598	1,497	1,402	1,313	1,230
Total	**4,698**	**4,400**	**4,121**	**3,860**	**3,615**

The conversion of voice minutes to bandwidth uses the following assumptions:

- Minutes per year per Erlang = 60*52*5*(1/0.081)/80%/1.23
  - This is based on there being **60** minutes in the busy hour, **52** weeks a year, **5** working days a week, **8.1%** of traffic coming during the busy hour (based on ILR data), an extra allowance of capacity for variations in traffic in the busy hour and over the course of the year of 23**%** (based on stakeholders' information), and **80%** of traffic in peak hours.
- A voice codec rate of (kbps) – 100 kbps.

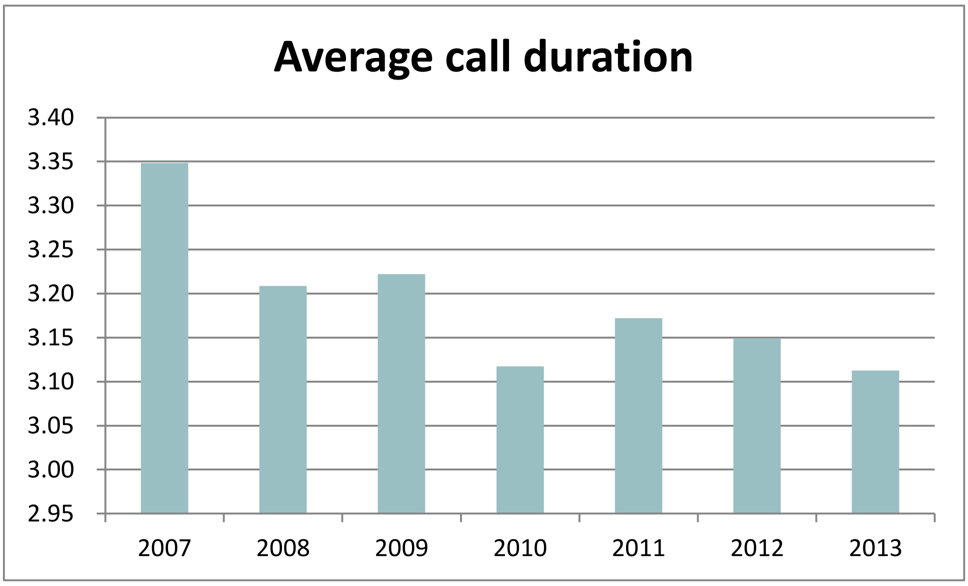
2.3.2 Voice calls

The conversion of minutes to busy hour call attempts (BHCA) is calculated assuming:

- An average call duration of 3.11 minutes; and
- There are 1.5 call attempts per call.

The average call duration is based on operator forecast data for 2013. The model assumes that the average call duration does not change over the period modelled. This is consistent with historic data provided in response to the data request (see below).

Figure 2. Average call data based on the operators' responses to the ILR's data request (minutes)



Source: Data provided by operators as response to ILR data request

2.3.3 Broadband bandwidth per subscriber

The table below sets out the model assumptions relating to broadband bandwidth per broadband line for different speeds. For standard and superfast broadband this is based on ILR data on the average bandwidth in the busy hour for ADSL (bhkbps). This is assumed to increase by 14% per year based on international benchmark data.

Table 11. Broadband bandwidth per line (bhkbps)

	2013	2014	2015	2016	2017
Standard Broadband (<24 Mbps)	171	195	222	253	289
Superfast Broadband (30 Mbps)	228	260	296	338	385
Ultrafast Broadband (50+ Mbps)	285	325	370	422	481

2.3.4 Bandwidth requirements for corporate lines

The model assumes the bandwidth per line (bhkbps) as set out in the table below. This is calculated using total bandwidth divided by the relevant number of corporate lines, based on the operators' responses to the ILR's data request.

Table 12. Bandwidth per corporate line (bhkbps)

	2013	2014	2015	2016	2017
Low speed traditional (< 2Mbit/s)	94	93	91	91	90
High speed traditional (>=2 Mbit/s)	9,259	9,259	9,259	9,259	9,259
Metro Ethernet	2,981	2,981	2,981	2,981	2,981

3 Cable and duct network

Three different sources of geographic data are used as inputs to the model for cable and duct requirements. These are summarised in the table below and then described in further detail.

Table 13. Geographic data used in the model

Data	Description
Location of potential users	Cadastre data on 151,064 premises[1] and CTIE (Centre de technologie informatique état) data showing number of physical persons and businesses resident at each address
Location and number of network nodes	Data provided by EPT in response to the ILR's data request the location of EPT's existing 71 TDM network nodes and the 106 FTTH nodes 1,258 sites under FTTC (VDSL)
Road network data	Cadastre data on 44,474 roads and 36,360 road intersections and ends

Estimates of the number of households in each address were made based on the number of people at the address, calibrated such that the average estimated household size across all premises was close to the Luxembourg average. The calibration also ensures that the number of households at each address is an integer.

3.1 Cable and duct network dimensioning assumptions

The table below sets out key assumptions used when dimensioning the cable and duct network.

1 A very small number of locations (7) are missing detailed address information and geocodes and have therefore been excluded from the sample.

Table 14. Key duct and cable dimensioning inputs

Parameter	Value	Note
Minimum number of copper pairs per potential subscriber	1.2	Based on all households and businesses. Used to dimension both D-side and E-side cable
Minimum fibres per customer – D-side	2	One spare fibre per customer
Minimum E-side fibre per P2P customer	1	Spare capacity included in cable so that minimum ratio is 1.1
Duct fill factor	0.8	20% of duct capacity is unfilled
Distance between jointing chambers	1,500m	Assumption provided by the operators in response to the ILR's data request
Distance between road crossing with 2-sided duct network	100m	Model assumption

Source: Frontier

3.2 Passive network dimensioning

A high level comparison of intermediate calculations shows the model appears to reflect operating conditions in Luxembourg (see table below).

Cable and duct network

Table 15. Cross-check of intermediate calculations

	EPT actual	BU-LRIC estimate
Kilometres of trench	4,000 – 5,000	5,051[2]
Number of poles	1800	-
Copper pair km ('000)	1,800	1,109
Fibre km ('000)		707
Distribution points (LV)	2251	1258 (VDSL sites)
MDF+PoP	49+80	106 FTTH PoPs
Splitters		1,808
Premises conncected to the network ('000)	147	163

3.3 Trench sharing

In the model, we consider how trenches, and therefore costs, can be shared with other utility providers in Luxembourg (e.g. joint digs with other utilities).

The table below sets out the percentage of trenches shared and the proportion of costs that would be incurred by an efficient network operator today. This is based on the operators' response to the ILR's data request on historic levels of trench sharing.

2 Of which 402 km is the second trench on road segments with trench on both sides

Table 16. Trench sharing and implied cost saving

	Percentage of total shares	Saving on trenching costs
No sharing	10%	0%
Two thirds of trench used by modelled operator	60%	33%
Half of trench used by modelled operator	20%	50%
One third of trench used by modelled operator	10%	66%

Note: It follows from these assumptions that the modelled operator would receive an effective discount of 37% on trenching costs on average throughout its network. This is calculated as the weighted average.

4 Core network hierarchy and number of nodes

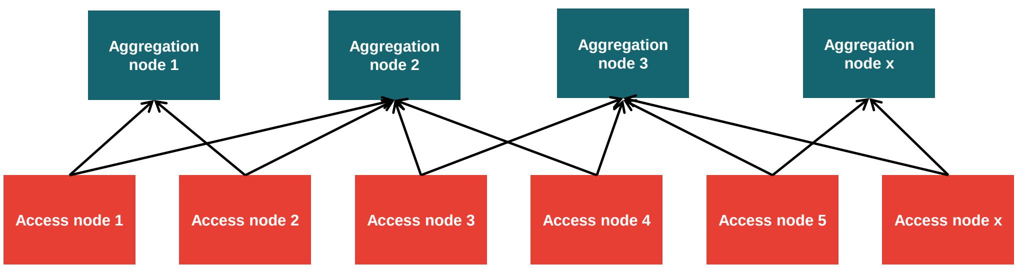
The table below summarises the number of nodes in the core network, and assumptions on resilience.

Table 17. Core network hierarchy and resilience

Layer of the network	Number of nodes	Resilience assumptions
Access nodes	106	Each access node is connected to 2 aggregation nodes
Aggregation nodes	21	Each aggregation node is connected to 2 IP Edge nodes
IP Edge nodes	9	Each IP Edge node is connected to 2 IP Core nodes
IP Core nodes	4	All IP Core nodes are fully meshed

Each access node is connected to two aggregation nodes for resilience (dual homed). There are 21 aggregation nodes in total. This relationship is graphically illustrated in the figure below.

Figure 3. Illustration of the resilience assumption for the connections between access nodes and aggregation nodes

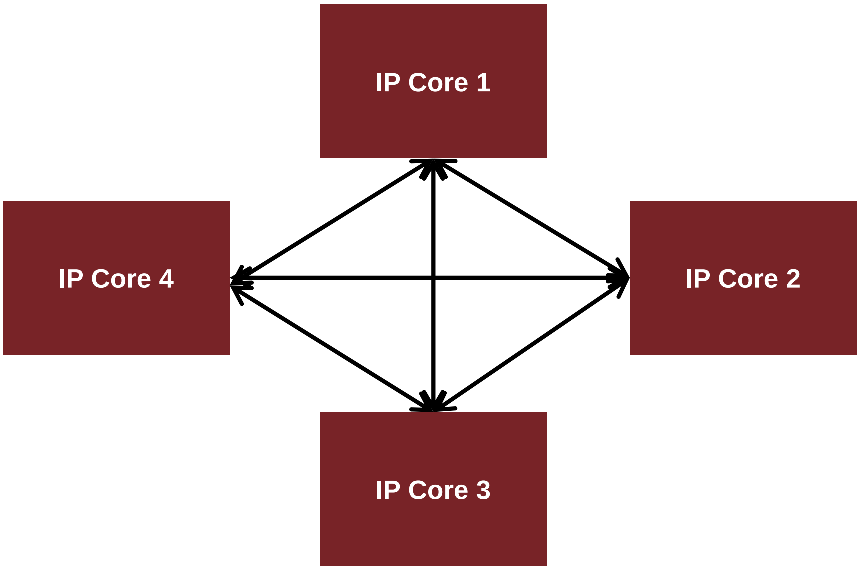


Higher levels of the network are also dual homed:

- Aggregation nodes (21) to IP Edge nodes (9); and
- IP Edge nodes (9) to IP Core nodes (4).

However, all IP Core nodes are fully meshed. This means that every IP Core node is connected to every other IP Core node. This is graphically illustrated in the figure below.

Figure 4. Illustration of the resilience assumption for the IP Core – fully meshed



Core network hierarchy and number of nodes

5 Equipment costs and dimensioning rules

The section sets out for each of the main equipment categories:

- Technical specification of network equipment within that category;
- Dimensioning rules used to determine the amount of equipment required;
- GRC (expressed in 2011 prices); and
- Operating costs.

5.1 Main cost categories

This section sets out the asset cost categories included in the model. It then lists the cost categories that account for the large majority of annualised costs in the model.

The table below sets out the network equipment modelled under each type of network element included in the model.

Table 18. Cost categories

Network element	Modelled network equipment
Aggregation	10-Port 1GigE
Aggregation	12-Port 10GigE
Aggregation	20-Port 1GigE
Aggregation	4-Port 10GigE
Aggregation	8-Port 10GigE
Aggregation	Alcatel-Lucent 7750 SR12
Aggregation	Alcatel-Lucent 7750 SR7
Aggregation	Racks
Aggregation	Space
BRAS	Juniper MX960
BRAS	Racks
BRAS	Space
Core fibre	FTTH-LWL-Micro-Câble 144 fo
Core trench	Duct
Core trench	Trench Rural
Core trench	Trench Suburban
Core trench	Trench Urban
Core trench	Trench Urban high cable density
Drop cable and NTE - copper	Drop cable and NTE - copper
Drop cable and NTE - FTTC	Drop cable and NTE - FTTC
Drop cable and NTE - GPON	Drop cable and NTE - GPON
Drop cable and NTE - P2P	Drop cable and NTE - P2P
D-side copper	Duct
D-side copper	Erdkabel A-02YSF(L)2Y1200X2X0.5
D-side copper	Erdkabel A-02YSF(L)2Y1800X2X0.5
D-side copper	Erdkabel A-02YSF(L)2Y2000X2X0.5
D-side copper	Erdkabel A-2YF(L)2Y 6X2X0.4
D-side copper	Erdkabel A-2YF(L)2Y 10X2X0.4
D-side copper	Erdkabel A-2YF(L)2Y 20X2X0.4
D-side copper	Erdkabel A-2YF(L)2Y 50X2X0.4
D-side copper	Erdkabel A-2YF(L)2Y 100X2X0.4

D-side copper	Erdkabel A-2YF(L)2Y 200X2X0.4
D-side copper	Erdkabel A-2YF(L)2Y 300X2X0.4
D-side copper	Erdkabel A-2YF(L)2Y 400X2X0.4
D-side copper	Erdkabel A-2YF(L)2Y 500X2X0.4
D-side copper	Erdkabel A-2YF(L)2Y 600X2X0.4
D-side copper	Erdkabel A-2YF(L)2Y 1000X2X0.4
D-side fibre	Duct
D-side fibre	FTTH-LWL-Micro-Câble 4 fo
D-side fibre	FTTH-LWL-Micro-Câble 12 fo
D-side fibre	FTTH-LWL-Micro-Câble 24 fo
D-side fibre	FTTH-LWL-Micro-Câble 60 fo
D-side fibre	FTTH-LWL-Micro-Câble 96 fo
D-side fibre	FTTH-LWL-Micro-Câble 144 fo
D-side infrastructure	Access duct (primary)
D-side infrastructure	Access duct (secondary)
D-side infrastructure	Trench rural
D-side infrastructure	Trench suburban
D-side infrastructure	Trench urban
D-side infrastructure	Trench urban high cable density
E-Side copper	Duct
E-Side copper	Erdkabel A-02YSF(L)2Y1200X2X0.5
E-Side copper	Erdkabel A-02YSF(L)2Y1800X2X0.5
E-Side copper	Erdkabel A-02YSF(L)2Y2000X2X0.5
E-Side copper	Erdkabel A-2YF(L)2Y 6X2X0.4
E-Side copper	Erdkabel A-2YF(L)2Y 10X2X0.4
E-Side copper	Erdkabel A-2YF(L)2Y 20X2X0.4
E-Side copper	Erdkabel A-2YF(L)2Y 50X2X0.4
E-Side copper	Erdkabel A-2YF(L)2Y 100X2X0.4
E-Side copper	Erdkabel A-2YF(L)2Y 200X2X0.4
E-Side copper	Erdkabel A-2YF(L)2Y 300X2X0.4
E-Side copper	Erdkabel A-2YF(L)2Y 400X2X0.4
E-Side copper	Erdkabel A-2YF(L)2Y 500X2X0.4
E-Side copper	Erdkabel A-2YF(L)2Y 600X2X0.4
E-Side copper	Erdkabel A-2YF(L)2Y 1000X2X0.4
E-side fibre	Duct
E-side fibre	FTTH-LWL-Micro-Câble 144 fo
E-side infrastructure	Trench rural
E-side infrastructure	Trench suburban
E-side infrastructure	Trench urban
E-side infrastructure	Trench urban high cable density
IP Core	Alcatel-Lucent 7750 SR12
IP Core	Alcatel-Lucent 7750 SR7
IP Core	Racks
IP Core	Space
IP Core ports 10GE	12-Port 10GigE
IP Core ports 10GE	4-Port 10GigE
IP Core ports 10GE	8-Port 10GigE
IP Edge	Alcatel-Lucent 7750 SR12
IP Edge	Alcatel-Lucent 7750 SR7
IP Edge	Racks
IP Edge	Space
IP Edge ports 10GE	12-Port 10GigE
IP Edge ports 10GE	4-Port 10GigE
IP Edge ports 10GE	8-Port 10GigE
IP Edge ports 1GE	10-Port 1GigE
IP Edge ports 1GE	20-Port 1GigE
MDF	Large MDF
MDF	Medium MDF
Media Gateways	Media Gateways
Media Gateways	Space
MSAN equipment	7330 ISAM
MSAN equipment	7330 ISAM + 12 modules
MSAN equipment	7330 ISAM + 6 modules
MSAN equipment	Racks

MSAN equipment	Space
MSAN port	48 port copper module
MSAN port	Number of ports for MSAN Cu subscribers
MSAN port	Number of ports for VDSL subscribers
NMS	Network management systems
ODFs	ODFs
OLT Agg ports	12 port module allocated to VDSL
OLT Agg ports	24 port module allocated to VDSL
OLT Agg ports	36 port module allocated to VDSL
OLT chassis	ISAM 7360 FX16
OLT chassis	ISAM 7360 FX4
OLT chassis	ISAM 7360 FX8
OLT chassis	Racks
OLT chassis	Space
OLT GPON ports	16 port GPON module
OLT GPON ports	4 port GPON module
OLT GPON ports	8 port GPON module
OLT GPON ports	GPON subscribers
OLT P2P ports	12 port module allocated to P2P
OLT P2P ports	24 port module allocated to P2P
OLT P2P ports	36 port module allocated to P2P
OLT P2P software cost	P2P fibre ports
Remote VDSL chassis	7330 ISAM
Remote VDSL chassis	7330 ISAM + 12 modules
Remote VDSL chassis	7330 ISAM + 6 modules
Remote VDSL chassis	Cabinets
Remote VDSL chassis	Space
Remote VDSL ports	48 port copper module
Remote VDSL ports	Subscribers
Softswitches	Softswitches
Softswitches	Space
VOIP servers	VOIP servers

The main cost categories which contribute to calculated unit costs for call termination, local loop access and bitstream access are set out in the table below. These account for over 90% of annualised capital costs.

Table 19. Main Cost categories[3]

LLU (or equivalent)	Bitstream	Call termination
Trenching	MSAN equipment	Media Gateways
Jointing chambers	Network management system (NMS)	MSAN equipment
Copper cable	Core trenching	VOIP servers

[3] Model results are presented in real terms with 2013 as a base year.

Fibre cable	Softswitches
ODF	
MDFs	

5.2 Trench costs

Equipment for trenching depends on the Geotypes in which the trenching is required. The unit GRC of this trench (per metre) is set out in the table below.

Table 20. Unit GRC of trench

Geotype	GRC per metre (€)
Rural	40
Suburban	55
Urban	80
Dense Urban	120

Source: Operator data

5.3 Jointing chambers

Jointing chambers are included in the duct network with the frequency required for cable joints set out above in **Table 14**. The table below sets out the assumed GRC of jointing chambers in the modelled network.

Table 21. Unit GRC of jointing chambers

Geotype	GRC per chamber (€)
Rural	1,850
Suburban	1,950
Urban	2,100
Urban high cable density	2,200

Source: Operator data

5.4 Copper cable

Copper cable is deployed in a wide number of configurations taking account of the number of copper pairs required on a route. The following table shows the configurations and costs used.

Table 22. Copper cable GRC

Configuration	Cost per metre (€/m), including installation and jointing
Erdkabel A-2YF(L)2Y 6X2X0.4	2.03
Erdkabel A-2YF(L)2Y 10X2X0.4	2.16
Erdkabel A-2YF(L)2Y 20X2X0.4	2.43
Erdkabel A-2YF(L)2Y 50X2X0.4	3.16
Erdkabel A-2YF(L)2Y 100X2X0.4	4.32
Erdkabel A-2YF(L)2Y 200X2X0.4	6.10
Erdkabel A-2YF(L)2Y 300X2X0.4	8.85
Erdkabel A-2YF(L)2Y 400X2X0.4	12.64
Erdkabel A-2YF(L)2Y 500X2X0.4	7.87
Erdkabel A-2YF(L)2Y 600X2X0.4	11.08
Erdkabel A-2YF(L)2Y 1000X2X0.4	28.01
Erdkabel A-02YSF(L)2Y1200X2X0.5	46.43
Erdkabel A-02YSF(L)2Y1800X2X0.5	66.62
Erdkabel A-02YSF(L)2Y2000X2X0.5	66.59

Source: Operator data

5.5 Fibre cable

Fibre cable is deployed in a number of configurations taking account of the number of fibres required on a route. When a greater number of fibres are required, multiple cables can be deployed within a duct, using micro-duct. The following table shows the cable configurations and costs used.

Table 23. Fibre cable GRC

Configuration	Cost per metre (€/m), including installation and splicing
FTTH-LWL-Micro-Câble 4 fo	1.58
FTTH-LWL-Micro-Câble 12 fo	1.70
FTTH-LWL-Micro-Câble 24 fo	2.03
FTTH-LWL-Micro-Câble 60 fo	2.68
FTTH-LWL-Micro-Câble 96 fo	3.07
FTTH-LWL-Micro-Câble 144 fo	3.83

Source: Operator data

5.6 Optical distribution frame (ODF)

Based on operator data, ODFs are modelled as having 1,728 ports each and have a unit GRC of €56,117.60. ODFs are assumed to have a utilisation rate of 80%.

5.7 Main distribution frame (MDF)

There are two models of MDF available in the network, which vary in size. The details are provided in the table below. The model selects the most appropriate MDF at each relevant access node based on the level of demand.

Table 24. MDFs in the modelled network

	Number of ports	GRC
Variant 1	5,000	€ 87,294
Variant 2	10,000	€ 103,921

Source: Operator data for the 10,000 MDF. The cost of the 5,000 port MDF is 84% of the cost of the 10,000 port MDF. This has been estimated based on analysis of the relationship between the number of ports and the cost of MDFs. This is based on international benchmarks.

MDFs are assumed to have an utilisation rate of 80%.

5.8 MSAN equipment

Equipment in the "MSAN equipment" category consists of MSAN equipment itself as well as the racks and space required. The table below shows the GRC used for an MSAN unit. This is based on operator data on an outdoor MSAN with 1GE uplink. We have also listed the cost of a street cabinet and a rack.

Table 25. MSAN equipment unit GRCs

	Unit GRC (€)
MSAN Chassis	3,802.23
MSAN Chassis + 6 modules	7,604.46
MSAN Chassis + 12 modules	11,406.69
Cabinet	19,484
Racks	502

The GRC of the 'MSAN Chassis +6 modules' and the 'MSAN Chassis +12 modules' is estimated as twice and three times the cost of the 'MSAN Chassis respectively. We assume DSLAM and MSAN characteristics as outlined in the table below.

Table 26. DSLAM and remote MSAN characteristics

	MSAN Chassis	MSAN Chassis + 6 modules	MSAN CHassis + 12 modules
MDA/ISA slots	6	12	18
Footprint per rack (m2)	0.12	0.12	0.12

We assume 48 port copper modules with 70% utilisation on 1GB and 10GB uplinks.

The model calculates the space required to accommodate all equipment in the network. The cost of the space required is modelled to be € 3,381.75 per square metre. This is based on a weighted average over different morphologies, as set out in the table below, and based on operator data.

Table 27. Cost of space for equipment in the model

	Weighting	GRC per sqm of building
Centre-ville	50%	4,429
Metropole	25%	2,584
Rural	25%	2,085
Weighted average	-	**3,381.75**

Source: Operator's data.

5.9 Network management system

The GRC of the network management systems (NMS) modelled in the network is € 3,745,901. This is based on international benchmarks.

5.10 Media Gateways

The GRC of the Media Gateways (MGWs) modelled in the network is € 227,916.99 based on operators' responses to the ILR's data request.

The table below describes the characteristics of the media gateways modelled. The model assumes that there is a minimum of 2 media gateways in the modelled network.

Table 28. Media gateway characteristics

	Media gateway
Media Gateway capacity (ports)	3,906
Maximum utilisation	70%
Additional resilience	100%

5.11 VOIP servers

Equipment in the "VOIP servers" category consists of only the VOIP server itself.

We assume following number of servers based on operator data on the actual number of servers. The total GRC of these servers is around € 6,737 each based on operator data.

Table 29. VOIP servers

	Quantity
VOIP test servers	23
VOIP live servers	28
TOTAL	**51**

5.12 Softswitches

Equipment in the "Softswitches" category consists of softswitches themselves and the space required. The GRC of softswitch is set at € 105,656.00. This is based on international benchmarks. The unit GRC of the space required (per sqm) is calculated as described above.

For softswitches, the we assume a capacity of 2,250,000 busy hour call attempts and a utilisation rate of 70%.

6 Asset lives and price trends

The table below sets out the asset lives and assumed rate of change of equipment prices (price tilts) used in the model.

Table 30. Asset lives and price tilt

Asset type	Asset life (years)	Price tilt (nominal)
Duct and trench	40	2%
Copper	20	2%
Fibre	20	2%
Space	50	2.5%
Chassis (access nodes)	5	-5%
Chassis (non-access nodes eg. aggregation, IP Edge, IP Core etc.)	7	-5%
Ports	5	-5%
Port software	5	0%

The asset lives for duct and trench, and copper are based on operator data. These modelled asset lives and price trends are in line with international benchmarks.

In order to use real prices in the model, there is an adjustment for general price inflation. This is sets at 2% (in line with the inflation forecast used in the WACC estimation, described in the annex to this document).

7 Other costs

In addition to the annualised costs of network equipment, the model also includes the following costs:

- Operational expenditure;
- Power and air-conditioning costs;
- Wholesale specific costs; and
- Common costs.

The data and assumptions used to calculate these are described in the rest of this section.

7.1 Operational expenditure

Operational expenditure is calculated in different ways depending on the type of network equipment.

For core network equipment, annual operating expenditure is assumed to be 4% of network GRC. This is based on information provided to the ILR in response to the data request on operational expenditure and the gross book value (GBV) of core network assets.[4] This is lower than observed in some other BU-LRIC models developed in Europe. However, we note that there is a very wide range of estimates used (from 4% to 80%) depending on the network asset and the model. Nevertheless, the data provided appears to provide a reasonable estimate of the operating costs an efficient operator would face in Luxembourg.

For access network equipment, operating costs are assumed to be on a per subscriber basis (€ 2.12 per subscriber per month). This is based on analysis of international benchmark data adjusted for differences in labour costs. This represents 2.1% of the GRC of the access network.

7.2 Power and air conditioning costs

Power and air conditioning costs are estimated on a per kw basis (€2,442). This is based on analysis of international benchmarks of the cost of electricity for network equipment and air-conditioning, air-conditioning equipment and space for power equipment (i.e. it is a "fully loaded" costs rather than just being the

4 This includes maintenance, expenditure on services provided by third parties and other costs for transmission and data network assets.

cost of the electricity paid to the electricity provider). This implies a total cost of power and air-conditioning of €772,000 in 2013.

7.3 Wholesale specific costs

Wholesale specific costs are assumed to be 25% of other costs (annualised capital costs plus operational expenditure plus power and air-conditioning costs). This is based on analysis of international benchmark data. This is applied to the following products:

- Call origination;
- Call termination (under the LRAIC approach but not under the pure LRIC estimation); and
- Call transit

7.4 Common costs

Common costs are assumed to be 6% of all other costs (annualised capital costs plus operational expenditure plus power and air-conditioning costs plus wholesale specific costs). This is based on operator data and is consistent with international benchmarks.

The French BU-LRIC model includes a 5% mark-up for common costs but appears to make no allowance for interconnection specific costs (wholesale billing, liaison costs). The Swedish model contains a small common cost mark-up (3%) but a very high interconnection specific mark-up (26%). There are also significant mark-ups for other wholesale services. Finally the Danish model allows for a 15% mark-up for access common costs and a 17% mark-up for core common costs. In addition, there are product specific mark-ups (including a 25% mark-up for termination services).

8 WACC estimation

We estimate a pre-tax real WACC of 9.11% including an NGA risk premium (6.61% excluding the NGA risk premium). The table below sets out our estimates of the parameters used to derive this. The estimation of these parameters is described in further detail in an annexe to this document.

Table 31. Estimate of the parameters used in the WACC estimate

Parameter	Value
Risk free rate	3.25%
Equity risk premium	6.00%
Equity beta	0.80
Debt premium	1.60%
Gearing	40%
Inflation rate	2.00%
Corporate tax rate	28.8%
Nominal cost of equity	8.07%
Nominal cost of debt	4.85%
Post-tax-nominal WACC	6.22%
Pre-tax-nominal WACC	8.74%
Pre-tax real WACC	6.61%
Pre-tax real fibre risk premium	2.5%
Pre-tax real WACC + risk premium	**9.11%**

Source: Frontier Economics

As the NGA risk premium is only relevant to NGA specific assets. Therefore, the following categorisation is made of different network elements in order to determine which WACC should apply.

Table 32. Estimate of the parameters used in the WACC estimate

ID	Network element name	NGA/non-NGA asset
1	D-side fibre	NGA
2	E-side fibre	NGA
5	D-side copper	non-NGA
6	E-Side copper	non-NGA
12	D-side infrastructure	NGA
13	E-side infrastructure	NGA
16	Remote VDSL chassis	NGA
17	Remote VDSL ports	NGA
18	ODFs	NGA
19	OLT GPON ports	NGA
20	OLT P2P software cost	NGA
21	OLT chassis	NGA
22	OLT P2P ports	NGA
23	OLT Agg ports	NGA
24	MDF	non-NGA
25	MSAN port	non-NGA
26	MSAN equipment	non-NGA
27	Aggregation	non-NGA
28	IP Edge ports 1GE	non-NGA
29	IP Edge ports 10GE	non-NGA
30	IP Edge	non-NGA
31	IP Core ports 10GE	non-NGA
32	IP Core	non-NGA
33	BRAS	non-NGA
34	NMS	non-NGA
35	Softswitches	non-NGA
36	Core transmission equipment	non-NGA
37	Media Gateways	non-NGA
38	VOIP servers	non-NGA
39	Core fibre	non-NGA
40	Core trench	non-NGA

9 Sensitivity analysis

This section describes the sensitivity analysis conducted as part of the model development. The purpose is to consider how the model results change as a result of changes to key input assumptions.

We describe qualitatively how changes in input assumptions affect intermediate calculations and the models results in order to provide transparency on how the model works and to demonstrate that the model is working in the way that we would expect.

The table below summarises the key input assumptions that are varied as part of the sensitivity analysis. These are discussed in more detail throughout this section.

Table 33. Inputs in the sensitivity analysis

Trenching costs	Demand forecast
Trench sharing	Asset price trends
Cost of jointing chambers	Asset lives
Cost of space	WACC
Number of POPs	Operating costs
Access technology type	Common costs

9.1 Trenching costs

In Section 0, we reported the trenching costs applied in the model. These figures were based on the operators' responses. We have also considered high and low scenarios. These scenarios are set out in the table below.

Table 34. Trenching costs – GRC per metre

Geotype	Base case	High	Low
Rural	40	50	30
Suburban	55	69	41
Urban	80	100	60
Urban high cable density	120	150	90

The high scenario is the base case plus 25%, and the low scenario is the base case minus 25%.

Under the high scenario trenching costs are higher in each geotype. The impact on the final results is greater for local loop unbundling where trenching costs represent a significant proportion of total costs. For example, the cost of copper LLU increases by around 10% and under the low scenario, the cost of copper LLU decreases by around 10%.

9.2 Trench sharing with other utility operators

In Section 3.3, we report the base case input assumption for trench sharing with other utility operators. In the operators' responses to the ILR's data request, it was reported that historic levels of trench sharing were higher than levels observed today. Based on historic figures, the average effective discount on trenching costs was 37%, compared to only 22% today.

If we estimate costs using the current levels of trench sharing, there is less sharing of costs and therefore the costs of services increases. This effect is greater for services for which trenching costs represent a greater proportion of total costs – for example, the cost of copper LLU increases by around 9% using current levels of sharing compared to historic levels of sharing.

9.3 Cost of jointing chambers

The table below shows the cost information used in the base case and alternative scenarios for jointing chambers in different morphology types (these are required in the trench network). The base case is based on operators' responses to the ILR's data request. The high scenario is the base case plus 25%, and the low scenario is the base case minus 25%.

Table 35. Cost of jointing chambers (EUR)

	Base case	High	Low
Rural	1,850	2,313	1,388
Suburban	1,950	2,438	1,463
Urban	2,100	2,625	1,575
Urban high cable density	2,200	2,750	1,650

Under the high scenario, costs increase for services that use trenching. This is because all jointing chambers in the network are now more expensive. For example, the cost of copper local loop unbundling increases, while the impact on traffic services is smaller as the proportion of costs related to infrastructure is lower. In the high scenario local loop unbundling increases and in the low scenario decreases by about 4%.

9.4 Number of POPs

As reported in Section 3.2, we model a network with 106 access nodes. This is based on the number of FTTH sites in EPT's network.

We have also modelled a scenario with only 71 access nodes. This is based on the number of sites in EPT's traditional TDM network, i.e. MDF sites.

With fewer nodes in the network, the average local loop length increases. This means that cable costs, and jointing costs for copper, also increase. However, the impact on the cost of copper LLU is relatively small – only a 2% increase in costs.

However, costs in the core network decrease. This is because there are fewer nodes requiring fewer pieces of equipment and buildings and fewer transmission routes. Therefore, with 71 nodes in the network, the cost of traffic services such as bitstream and Ethernet services decrease. However, the impact is still relatively small – there is a 4% decrease in the costs of these services.

9.5 Choice of access technology

EPT currently uses the following access technologies in Luxembourg:

- Copper to the MDF;

- Fibre to the cabinet (FTTC);
- GPON fibre; and
- P2P fibre

In Section 2.2.2 we set out the assumed breakdown of subscribers across the different access technologies – the majority of subscribers are assumed to be served using copper to the MDF technology.

We have also considered how the results change when we consider a network with only one access technology type. We have repeated this sensitivity analysis to cover all four technology types.

Having only one technology type reduces the need for multiple pieces of equipment at access nodes and allows for higher utilisation rates. In addition some components make a large contribution to the blended cost of services in the base case. This means that the removal of the components associated with these technologies can result in a significant reduction in costs.

Under each of the 100% scenarios, the cost of the relevant unbundling service decreases. The decrease is least pronounced for copper to the MDF. This is because, as discussed in Section 2.2.2, the majority of subscribers in Luxembourg are already served by copper to the MDF technology. Therefore the scope for cost reduction is lower.

The biggest impact is on FTTH P2P. The cost of fibre LLU decreases by around 76% under the 100% fibre scenario. In contrast to the copper to the MDF scenario, this is because P2P fibre is the least popular access technology. And therefore it has the biggest scope for cost savings.

An all GPON fibre access network offers the cheapest solution, followed by FTTC. An all P2P fibre access network is cheaper than an all copper access network. However, there is not much variation in the results.

9.6 Cost of space

In Section 5.8 we listed our assumption that space costs € 3,381.75 per metre square. We have assumed a high scenario of € 4227.19 (the base case +25%) and a low scenario of € 2536.31 per metre square (the base case -25%).

Costs increase under the high scenario – and they decrease under the low scenario. However, the impact is relatively small. The impact is greatest on the services where equipment (and therefore the space required to accommodate it) represents a high proportion of total costs – for example traffic services. However, even for these services there is only a 2% change. The impact on Copper LLU is lower than 1%, the impact on 2% Fibre LLU is about 2%.

9.7 Demand forecast

In Section 2.3 we set out the model assumptions on the growth of traffic per subscriber. This is split across voice (with a further breakdown across off-net / on-net etc.), and data (split across different speeds).

We have considered a high scenario where we assume that the average annual growth rate in traffic per subscriber is 10 percentage points higher than under the base case forecasts.

With higher traffic volumes on the network, we observe that costs for traffic services decrease, and there is no change on unbundling services.

For traffic services, this is because with greater volumes of traffic there are greater utilisation rates for equipment in the network. And this is enough to offset any instances where more equipment needs to be dimensioned. Therefore, on the whole, unit costs decrease. The cost of traffic services decrease on average by approximately 8%.

There is no impact on the cost of unbundling services. This is because even with greater volumes of traffic, no extra investment in cables and trenching infrastructure is required.

For the same reasons, the opposite results hold for a low scenario – where we assume that the average annual growth rate in traffic per subscriber is 10 percentage points lower than under the base case forecasts. The cost of traffic services increase, while unbundling services remain unchanged.

9.8 Asset price trends (% price increase p.a.)

In Section 6 we set out the main asset types used in the modelled network (for example, duct and trench, copper, fibre and so on). For each of these, we also list the base case assumption of price trends.

The table below reports the high and low scenarios that have been tested, relative to the base case.

Table 36. Asset price trends used in sensitivity analysis

Asset category	Base case	Low	High
Duct and trench	2.0%	1.50%	2.50%
Copper	2.0%	1.50%	2.50%
Fibre	2.0%	1.50%	2.50%
Space	2.5%	1.88%	3.13%
Chassis (at access nodes)	-5.0%	-6.25%	-3.75%
Chassis (the rest)	-5.0%	-6.25%	-3.75%
Ports	-5.0%	-6.25%	-3.75%
Port software	0.0%	-2.00%	2.00%

Under the high price trend scenario we multiply the base case price trends by 1.25. Under the low scenario we multiply the base case by 0.75. For example, the price trend of duct and trench in the base case is 2%. Therefore under the high scenario, we assume a price trend of 2.5%. For port software, which has a price trend of 0%, we assume a price trend of +2% in the high scenario and -2% in the low scenario.

The results show only a relatively small change in the cost of services – within +/-3% of the base case for all services under the low and high scenarios respectively.

Increasing the rate at which asset prices increase (and reducing the amount by which they fall where price trends are negative) leads to lower costs over the modelled period. This is because of the tilted annuity assumption which means that a lower proportion of costs are recovered early on in the asset lifetime when asset prices are increasing. We also observe that the impact is greatest for services that are capital intensive with long lived assets, i.e. access services. This is in line with what we would expect. The opposite is also true for the decreasing the rate at which prices increase (the low price trend scenario).

9.9 Asset lives

In Section 6 we list our base case model assumptions on asset lifetimes. The table below reports the assumptions for the high and low scenarios relative to the base case.

Table 37. Asset price trends used in sensitivity analysis

Asset category	Base case	Low	High
Duct and trench	40	30	50
Copper	20	15	25
Fibre	20	15	25
Space	50	37.5	62.5
Chassis (at access nodes)	5	3.8	6.3
Chassis (the rest)	7	5.3	8.8
Ports	5	3.8	6.3
Port software	5	3.8	6.3

Under the high scenario, we assume asset lifetimes 25% greater than under the base case.

As we would anticipate, increasing the asset lifetimes leads to lower product and service costs. This is because increasing the asset lifetime increases the time period over which costs are recovered and hence lead to lower amortisation in each year. While this also increases the NRC of assets and therefore the cost of capital, this is more than offset by the lower amortisation charges. The impact is a less than 10% reduction in costs for all services.

Similarly, decreasing asset lifetimes decreases the time period over which costs are recovered and hence leads to higher amortisation in each year.

9.10 WACC (real pre-tax)

The base case assumption for the WACC used in the model is 9.11% (See Section 8). Under the high scenario of 11.39% (which is the base case multiplied by 1.25) we would expect an increase in the overall results. This is because capital costs will be greater with a higher WACC. We also test a low scenario with the

WACC set to 6.83% (which is the base case multiplied by 0.75). We would expect lower overall results as capital costs will be lower.

As we would expect, the impact of changing the WACC is greatest for services using the access network (where services are capital intensive and make use of longer lived infrastructure assets). The largest impact is on unbundling services where the capital intensity of the services and life of the assets used is longer (meaning that the NRC to which the WACC is applied is higher). For these services the increase in costs is between 10% and 20%. For traffic services the increase is less than 10%.

9.11 Operating costs

In Section 7.1 we describe that approach for modelling operating costs (opex). There are separate approaches for the:

- Access network – where opex is assumed at € 2.12 per subscriber per month ; and
- Core network – where opex is assumed to be 4% of network GRC

We consider high and low scenarios for access and core opex individually. The high scenarios are the base case plus 25%, and the low scenarios are the base case minus 25%.

As we would expect, under the high scenarios, product and service costs increase. Similarly, under the low scenario, overall costs fall. The effect is larger for those services that are less capital intensive and for which operating costs represent a relatively larger share of total costs (i.e. traffic services rather than access services). However, the impact on the results is relatively small – with no change greater than 5%.

9.12 Common costs

In the model base case, we assume a common cost mark-up of 6% applied to annualised capital costs plus operational expenditure plus power and air-conditioning costs plus wholesale specific costs (see Section 7.4). Under the high scenario we assume a mark-up of 7.5% - which is the base case plus 25%, and under the low scenario we assume a mark-up of 4.5% - which is the base case minus 25%. As we would expect, lowering the amount of common costs leads to lower product costs (and vice versa). However, the impact is small. No results change by more than 2%.

Annexe 1: WACC estimation

Our approach takes account of:

- The approach adopted by the ILR in previous regulatory decisions;
- Consideration of the risk of investment in Luxembourg;
- The WACC estimate used in other comparable European countries; and
- The methodology adopted by other European regulators.

The rest of this section sets out:

- A description of what the cost of capital is conceptually;
- The rationale for calculating a fixed network specific WACC;
- The form of WACC used and how corporation tax and inflation are accounted for ;
- A summary of the parameters used in the WACC estimate and the approach used to estimate them;
- A comparison of the WACC estimate with those from a sample of European jurisdictions; and
- Further details of the source data used.

What is the cost of capital?

The cost of capital is the minimum expected rate of return necessary to attract capital to an investment. As described in the table below, there are four essential features of a regulatory cost of capital.

Table 38. Four essential features of the cost of capital

Feature	Description
Reflects risk of investment	All else being equal, the greater the risk, the great the rate of return that investors will demand
Reflects opportunity cost	The cost of capital must be sufficient to compensate an investor for the next best investment
Is forward looking	Future returns are uncertain so the cost of capital is the *expected* (in a probabilistic sense) rate of return
Is determined by the market	The cost of capital is determined by the balance between the supply and demand for capital

Source: Frontier Economics

The cost of capital is typically measured using the weighted average cost of capital (WACC). This takes account of the main sources of funding usually available to companies: debt and equity. It also takes account of the relative proportions of mix of capital through gearing (the proportion of debt within the capital structure). The WACC cannot be observed directly but must be estimated using market data on certain parameters. Some of these are specific to the market (i.e. not specific to a particular business) whereas others are business specific. The business specific parameters are usually estimated using reference data from existing comparator firms.

Estimating the cost of capital for next generation access (NGA) networks is very challenging for a number of reasons:

- NGA technologies are relatively nascent;
- Deployment of network has been slow meaning there is limited evidence on the cost of rolling out networks and the level and nature of demand;
- There are very few comparators with extensive NGA networks;
- There are no NGA network operators that do not also invest in other activities; and
- There may be risks that are specific to NGA (as recognised by the European Commission (EC) Recommendation on NGA regulation).

Given these challenges, we consider that a reasonable approximation for the WACC of an NGA network is the WACC for a conventional fixed operator (copper based access network) plus an NGA risk premium in the regulatory cost of capital.

Fixed network WACC

The European Regulators Group (ERG) recognises that different parts of a business may be subject to different levels of risk. Further, operators commonly make investment decisions at a project or activity level. In other European jurisdictions, regulators have typically set the regulatory WACC at the level of the fixed network business.[5] Therefore, we estimate the WACC of a fixed network operator in Luxembourg.

Regulators have typically distinguished between the cost of capital for the fixed network business and that for the mobile network business even though operators are typically integrated. This is largely for historic reasons as mobile networks were newer and therefore perceived as riskier investments compared to fixed networks.

There are three potential sources of difference in the WACC for fixed and mobile networks:

- The level of gearing;
- The asset beta; and
- The debt premium.

These differences are driven by differences in the underlying cost structure of fixed and mobile networks. In particular, fixed networks are characterised by higher levels of fixed costs meaning that they are less able to respond to fluctuations in demand. These are also driven by differences in the characteristics of demand for fixed and mobile services.

The other parameters used in the WACC estimate are not firm-specific and would therefore do not vary depending on whether the WACC relates to a fixed or to a mobile network.

In recent years regulatory WACCs for fixed and mobile networks have converged. This may mean that in practice the regulatory WACC may be the same for fixed and mobile networks because of difficulties in estimating the input parameters reliably.

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5 The exception to this is Ofcom in the UK which uses a lower WACC for Openreach than for the rest of BT. Openreach is the functionally separate part of BT Group that provides access network infrastructure.

Form of WACC used – tax and inflation

WACC can be expressed either in real or nominal terms, with the former excluding the impact of inflation. The choice over whether a real or nominal measure should be used will depend on how it will be used.

The valuation of assets in the cost model takes account of how the value of these assets changes over time. Since the cost model makes allowance for inflation in this way, no inflation allowance should be made in the WACC. In other words, the WACC should be estimated on a real basis.

The ILR's cost model does not make specific allowance for corporate taxation. However, the model will be used to assess the SMP operators' compliance with its cost orientation obligations. Therefore, the assessment of prices should make an allowance for corporation tax since this is a cost that would be incurred by an efficient network operator. Therefore the WACC should be estimated on a pre-tax basis.

The pre-tax real WACC can be expressed formulaically as:

$$\text{pre-tax real WACC} = \frac{1 + \text{pre-tax nominal WACC}}{1 + \text{inflation rate}} - 1$$

Where:

$$\text{pre-tax nominal WACC} = \frac{\text{Post-tax nominal WACC}}{1 - \text{corporate tax rate}}$$

And:

$$\begin{aligned}\text{post-tax nominal WACC} &= \big(\text{nominal cost of equity} \times (1 - \text{gearing ratio})\big) \\ &+ \big(\text{nominal cost of debt} \times \text{gearing ratio} \\ &\times (1 - \text{corporate tax rate})\big)\end{aligned}$$

The rest of this section sets out how we have estimated the components of the WACC estimate.

WACC estimate

We estimate a pre-tax real WACC of 9.11% including an NGA risk premium (6.61% excluding the NGA risk premium). The table below sets out our estimates of the parameters used to derive this. The estimation of these parameters is described in further detail in the rest of this section.

Table 39. Estimate of the parameters used in the WACC estimate

Parameter	Value
Risk free rate	3.25%
Equity risk premium	6.00%
Equity beta	0.80
Debt premium	1.60%
Gearing	40%
Inflation rate	2.00%
Corporate tax rate	28.8%
Nominal cost of equity	8.07%
Nominal cost of debt	4.85%
Post-tax-nominal WACC	6.22%
Pre-tax-nominal WACC	8.74%
Pre-tax real WACC	**6.61%**
Pre-tax real fibre risk premium	2.50%
Pre-tax real WACC + risk premium	**9.11%**

Source: Frontier Economics

The table below summarises the approach taken to estimating each of the parameters used in the estimate of the WACC. We then compared the estimated WACC with the regulatory WACC used in a number of other European jurisdictions (see Section 0). The approach, data used and conclusions are described in further detail in Section 0 - 0.

Table 40. Approach to estimating the cost of capital

Parameter	Approach to estimation
Risk free rate	Proxied using yields on very safe government bonds (Luxembourg government bonds are rated AAA)
Equity risk premium	Long run historic averages market returns above the risk free rate at the European and global level Historic risk premiums implied by current stock prices Survey of academics
Equity beta	Benchmarking against recent European regulatory decisions for fixed copper networks
Debt premium	Benchmarking against recent European regulatory decisions for fixed copper networks Corporate bond index data
Gearing	Benchmarking against recent European regulatory decisions for fixed copper networks
Inflation rate	Historic Euro area inflation ECB inflation targets Survey of professional forecasters
Corporate tax rate	KPMG Corporate and Indirect Tax Survey, 2012
NGA risk premium	Benchmarking against recent European regulatory studies

Source: Frontier Economics

Gearing

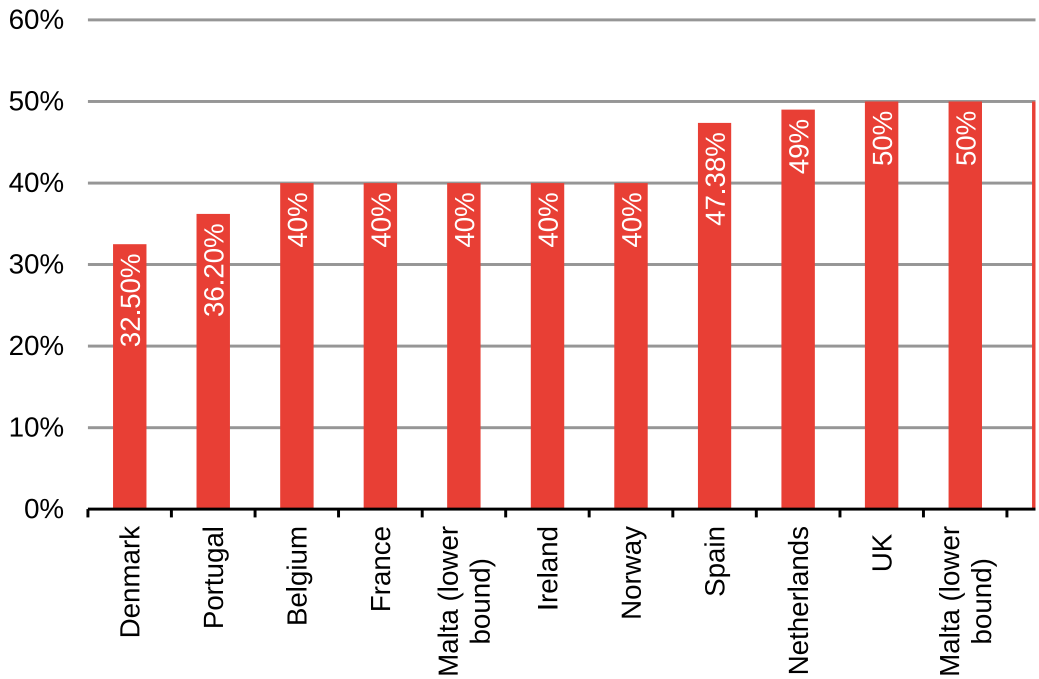
Gearing is the relative weight of debt and equity financing of a business. Gearing is used to estimate the cost of capital in two ways. First, it is used when transforming asset betas to equity betas (and vice versa). And second, it is used when calculating the capital structure weights in the WACC formula.

Some regulators match the gearing assumption to the business's actual level of gearing, whereas others determine a 'notional' gearing in order to incentivise the businesses to not adopt an inefficient level of borrowing.

The figure below shows recent estimate of gearing of fixed networks in Europe by regulatory authorities. It can be seen from the figure below that most regulatory estimates are within a relatively narrow range. This range is between 32.5% and 50% (with a mean of approximately 43%, and a median of 40%).

Given these estimates, we recommend a gearing assumption of 40%.

Figure 5. Recent regulatory estimates of gearing for fixed copper network operators



Sources: Various determinations by regulators or reports by their advisors (see References)

Notes: Some estimates relate to final determinations while others relate to consultations with stakeholders

Estimated nominal cost of equity

The cost of equity is the rate of return required by equity investors in order to compensate them adequately for:

- The risk they bear; and
- The opportunities they forgo in order to commit funds to the firm.

The cost of equity cannot be observed directly but must be estimated. The most common approach used by practitioners and regulators in the capital asset pricing model (CAPM).[6] When applied to equity capital, the CAPM can be written as:

$$cost\ of\ equity = risk\ free\ rate + \ market\ risk\ premium \times equity\ beta$$

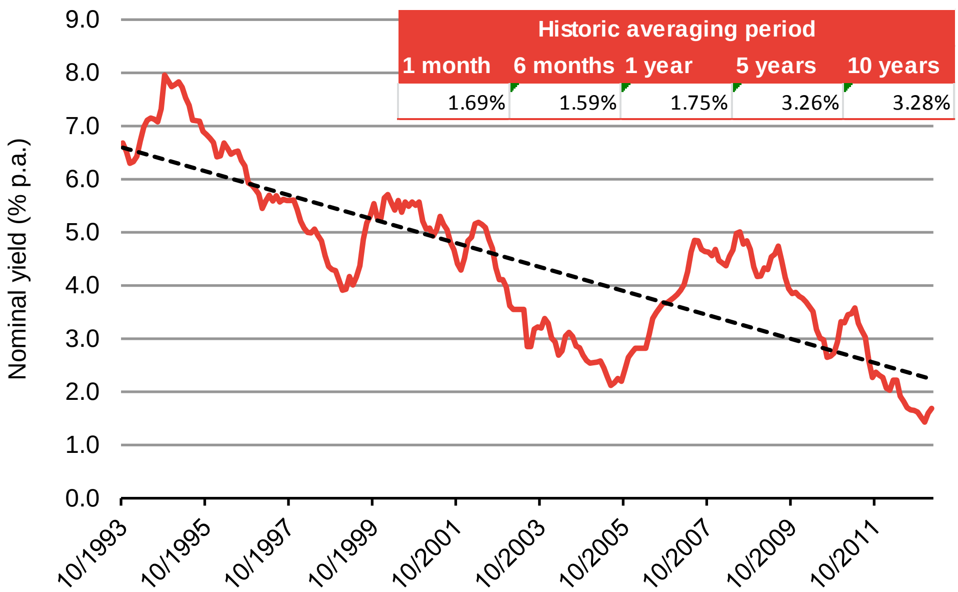
These parameters are described in further detail below.

Risk free rate

The risk free rate is the rate of return on a riskless asset. It is commonly proxied by yields on very safe government bonds. Luxembourg government bonds are rated AAA by S&P so these provide a reasonable proxy.

The figure below illustrates how nominal yields on Luxembourg government bonds have declined significantly over time.

Figure 6. Historic yields on Luxembourg government bonds



Source: ECB Statistical Data Warehouse

We note that a similar trend has occurred with yields on securities issued by other safe governments. This has been driven by high investor demand (i.e. a 'flight to safety' as investors have sought safe haven investments during recent financial crises).

[6] Wright, Mason and Miles (2003), ERG (2008).

As described above, the WACC and its components should be forward-looking. General expectations are that current low yields will not persist indefinitely because as the global economy recovers and market uncertainty declines, investors are likely to shift funds from safe assets towards riskier investments. This would drive up yields on government bonds. However, it is unclear when yields will recover to more 'normal' levels. Economic theory suggests that interest rates are likely to be mean-reverting. This means that it is reasonable to use historic averages to inform future risk-free rate expectations.

Historic medium to long-term historic averages suggest a risk-free rate ranging between 3.25% and 3.3%. We recommend conservative estimate of the risk-free rate of 3.25%.

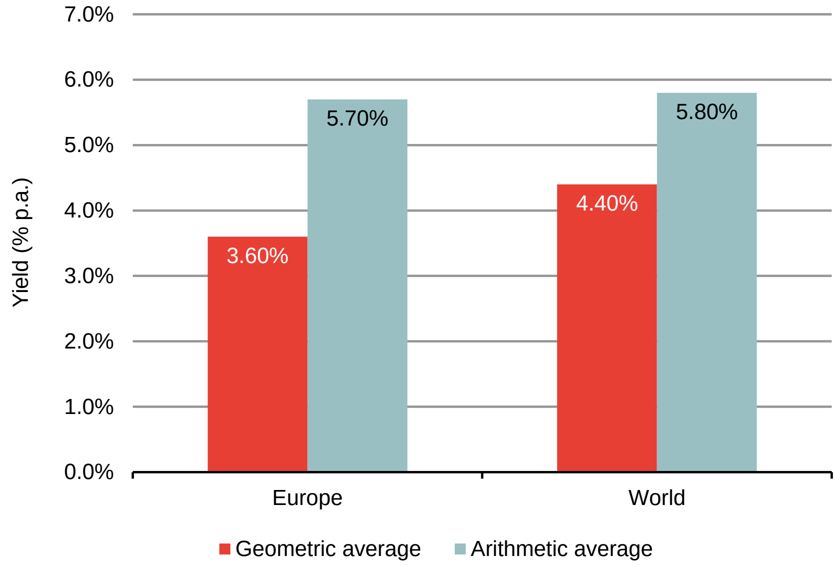
Equity risk premium

The equity risk premium (ERP) is the return over and above the risk free rate from holding a fully diversified "market portfolio". It is typically estimated using long run historical averages, short-run implied risk premiums and survey evidence. These are considered below.

Long run historical averages

The figure below shows long run historic averages of market returns in excess of the risk-free rate (from 1900 to date). This suggests estimates for the long-run ERP of 3.6% to 5.7% for Europe depending on whether a geometric of arithmetic average is used.

Figure 7. Long run historic averages of market returns



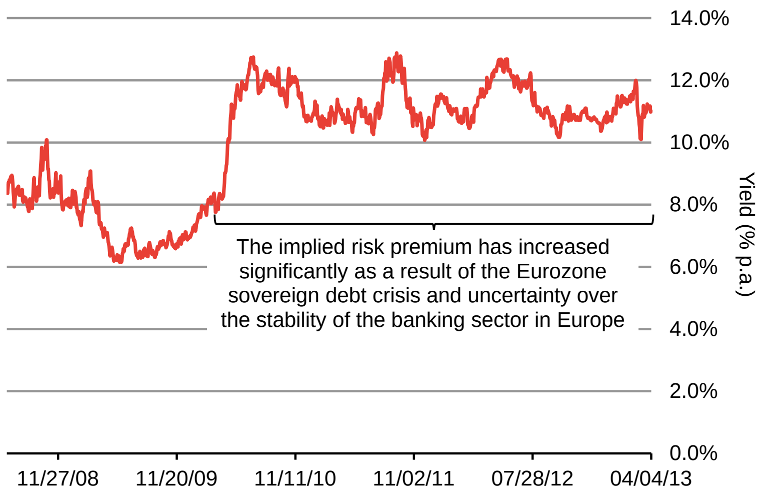
Source: Dimson, Marsh, Staunton (2012), Global Investment Returns Sourcebook

Short run implied risk premiums

Estimates of the ERP implied by current stock prices (from Bloomberg using the Dividend Growth Model) show that the current risk premium in Europe is approximately 11%. This reflects the current Eurozone and banking crises.

Annexe 1: WACC estimation

Figure 8. Implied risk premiums



Source: Bloomberg

Survey evidence

A survey of academics, analysts and executives, by Fernandez et al (2013)[7] suggests that the ERP required by investors in Luxembourg at present is 6.0%.

Proposed value

Given all the evidence, we consider that an estimate of 6% for the ERP is appropriate (slightly above the long-term historic average). This is consistent with the use of relatively long term view of the risk-free rate (5-10 years).Beta

Beta reflects the risk associated with the business that cannot be diversified away, and is measured as the correlation between returns on the business and returns on the market. We have obtained an estimate of beta by benchmarking recent European regulatory determinations.

The figure below shows recent estimates of asset betas for fixed copper line networks.[8] It can be seen that these estimates range between 0.39 and 0.60 (with a mean of 0.49 and a median of 0.49). Excluding the oldest sample estimate (Ireland 2008) makes very little difference to the sample average.

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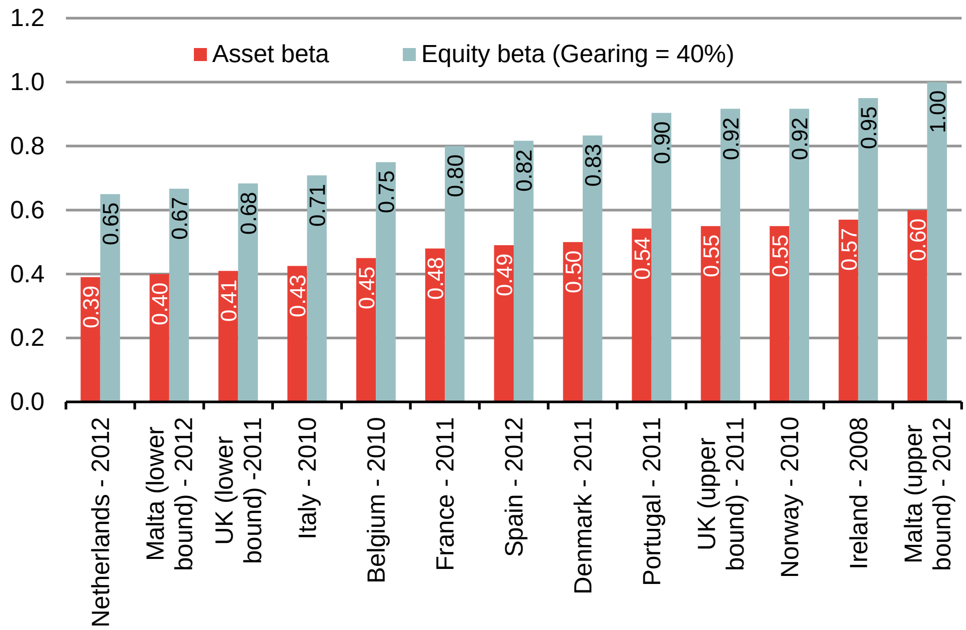
7 Fernandez, P., Aguirreamalloa, J., Corres, L. (2013), 'Market risk premium used in 82 countries in 2012: a survey with 7,192 answers', IESE Business School working paper.

8 The asset beta reflects the underlying business risk of the assets of the firm. It is calculated by removing the effect of gearing from the estimated equity beta through the process of de-levering.

Figure 9. Recent European regulatory estimates of asset and equity betas for fixed network operators



Sources: Various determinations by regulators or reports by their advisors (see References)

Notes: Some estimates relate to final determinations while others relate to consultations with stakeholders

Re-levering formula used in this calculation is the Miller formula: Equity beta = Asset beta/(1−Gearing)

The average equity beta over the regulatory sample, assuming a common gearing level of 40% (see below), is approximately 0.8. Re-levered regulatory estimates of asset betas imply an equity beta range of 0.65 to 1.00

Based on this, we recommend an equity beta estimate of 0.8.

Nominal cost of debt

The nominal cost of debt is the sum of the risk free rate and the debt premium. It can be expressed formulaically as:

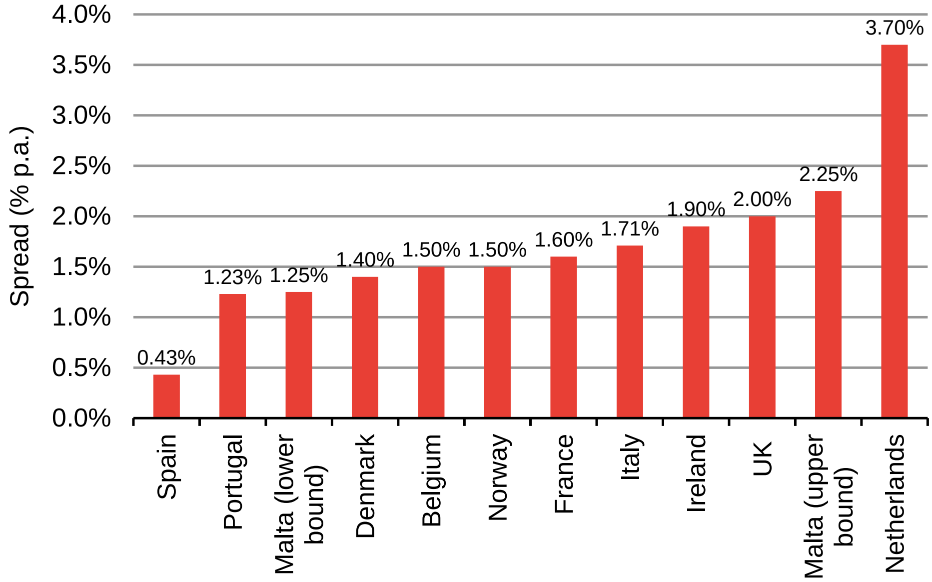
$$Nominal\ cost\ of\ debt = risk\ free\ rate + debt\ premimum$$

The estimation of the risk free rate is described above in Section 0. The estimation of the debt premium is described below.

The debt premium is the compensation to debt investors for credit and liquidity risks. We have estimated the debt premium using recent European regulatory determinations and bond index data.

The figure below shows recent regulatory estimates of the debt premium for fixed copper line networks. It can be seen that these have ranged between 0.43% and 3.70%.

Figure 10. Recent estimates of the debt premium

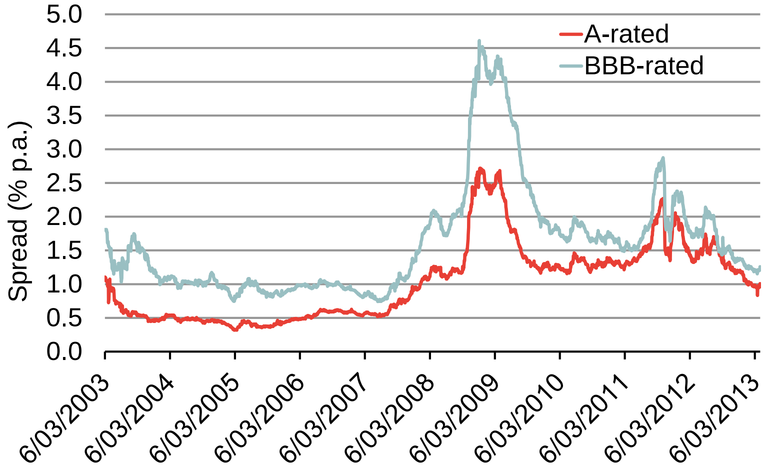


Sources: Various determinations by regulators or reports by their advisors; some estimates relate to final determinations while others relate to consultations with stakeholders

However, the Spanish and Dutch estimates appear to be outliers at each end of the range. Given the riskiness of the respective economies, we would expect that Spanish firms are likely pay significantly higher than regulator's estimate and firms in the Netherlands are likely to pay significantly less than the OPTA estimate. Excluding these two outliers results in a range of 1.23% to 2.25%, with an average of approximately 1.6%.

Corporate bond index data for European firms suggest that the 10-year average debt premium on 10-year A-rated bonds is 1.04%. The 10-year average is 1.62% for BBB rated bonds. This is illustrated in the figure below.

Figure 11. Fair value debt premium estimates for European corporates (10-year maturity)



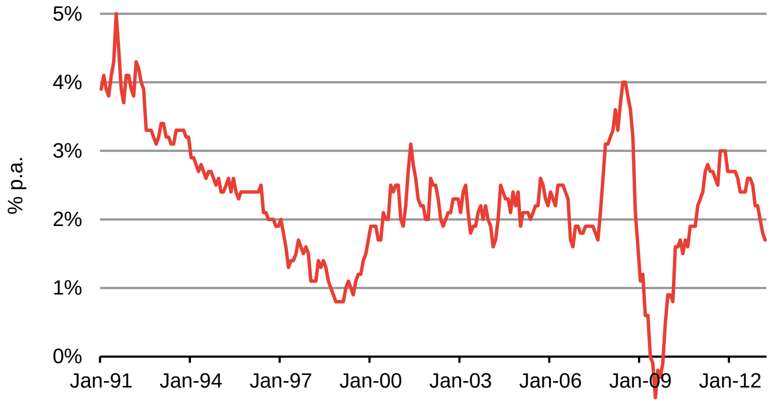
Source: Bloomberg composite index, Frontier calculations

Based on the evidence presented above, we recommend a debt premium estimate of 1.60%

Inflation and taxes

The ECB "aims at inflation rates of below, but close to, 2% over the medium term". However, the figure below shows how historic inflation in the Euro-area has been very volatile, particularly in the last five years. Average historic inflation over the past 10 years has been approximately 2.1% p.a.

Figure 12. Historic Euro-area inflation rates



Source: ECB Statistical Data Warehouse. European Commission (Eurostat) and European Central Bank

Annexe 1: WACC estimation

calculations based on Eurostat data

Notes: Euro area (changing composition) - HICP - Overall index, Annual rate of change, Eurostat, Neither seasonally nor working day adjusted

The ECB survey of professional forecasters is that average rate of inflation over the next five years will be (as at March 2013) 2.0% p.a.

Table 41. ECB survey of professional forecasters

Time period	Forecast
1 year ahead	1.70%
2 years ahead	1.80%
5 years ahead	2.00%

Source: ECB

Based on historic data and forecasts, we recommend an inflation estimate of 2.0% p.a.

The corporate tax rate in Luxembourg is currently 28.8%.[9] We have used a corporate tax rate of 28.8% in the WACC estimate.

NGA risk premium

The European Commission (EC) recognises that investment in NGA assets is risky given significant uncertainty over future demand, costs of deployment, technological progress, competition and macroeconomic uncertainty.[10] Given these uncertainties, and the fact that NGA investments are sunk once made, there potentially a material risk of assets being "stranded".

Given the high cost of investing in NGA, the option value of delaying investment may be significant. However, the option value of waiting would be lower if there is a real risk of competitive entry (i.e. if a rival may invest first in order to secure a first mover advantage).

Standard cost-based pricing models do not take account the option value of waiting. This is because these models typically ignore the flexibility that firms enjoy to alter the timing of investment in response to market conditions (i.e. delay in the face of uncertainty, and acceleration of investment plans in the face

9 KPMG Corporate and Indirect Tax Survey, 2012

10 EC Recommendation on NGA regulation, September 2010

of the threat of competitive entry). If the option value of delay is material, there are three main ways in which regulators could take account of this.

1. Rely on the market to mitigate risk;
2. Regulatory tools; and
3. Allowing a risk premium in the regulatory WACC.[11]

We describe below briefly each of these mechanisms. For the reasons below, we consider that the most appropriate approach would be to include a risk premium in the regulatory WACC.

Relying on the market to mitigate risk

There a number of ways in which operators in a competitive market can mitigate the risk that they face. Some examples are provided below.

- Operators can use up-front fixed term contracts that commit subscribers to a minimum contract duration. This would help to secure future revenues.
- Sharing the costs of rolling out the network with other parties helps to reduce the total cost faced by any one operator (and therefore spread the costs associate with potential stranding).
- Allowing operators to defer investment (for example, by not requiring operators to meet coverage targets that are too onerous) would mean that they would not have to invest today and could wait until market characteristics (both demand and supply side considerations) become more certain. However, this needs to be balanced against the wider public policy benefits of having superfast and ultrafast broadband coverage.
- Using capacity-based charges rather than usage-based charges can also help to make revenues more certain. This is because it may be unclear how subscribers will use new technology and therefore how much they will use superfast broadband services.

Other regulatory tools

Other regulatory tools include a regulatory "holiday" for a defined period of time in which the operator is subject to lighter touch or no regulation. This helps to increase the symmetry of returns. That is, typically regulation does not allow

11 This is based on the options identified by OPTA ("Policy rules tariff: Regulation for unbundled fibre access, December 2008); and in a report for the European Commission ("Costing methodologies and incentives to invest in fibre", a report for DG Information Society and Media, July 2012).

firms to earn profits above their regulatory cost of capital, However, regulation also does not typically allow operators to recover any losses if the investment turns out to be less profitable than expected (for example, because anticipated demand for services fails to materialise). Therefore, a regulatory holiday can allow a firm to earn higher returns to offset the risk of lower returns.

Another option would be to permit operators to recover their costs of investment even if the investment proves to be unsuccessful.

Both these options offer limited benefits which appear to be more than outweighed by their potential costs. In particular, a regulatory holiday could mean that a firm charges higher prices to consumers and this results in lower take up and usage of services than would be efficient. Further, allowing investors to recover the cost of stranded assets might distort incentives for efficient investment. This is because an operator could decide to invest in something even knowing that this would be unsuccessful since it would be allowed to recover these investment costs irrespective of future demand. Nonetheless, regulators in many other sectors (e.g. energy, water, airports) have chosen to adopt this approach because they have not wished to deter investments that they have deemed to be desirable from a social welfare perspective.

There is also an important role for regulators to provide a stable regulatory environment as this can help to reduce investment uncertainty.

Allowing a risk premium in the regulatory WACC

Allowing a premium in the regulatory WACC could help to reflect the risk that operators face in investing in NGA network rollout. We note that there are some limitations associated with this approach. In particular, it can be difficult (although not impossible) to take account of how the threat of competitive entry to the market erodes the option value (i.e. the potential value of waiting to invest is lower if there is a risk that another operator will invest sooner). Also, there has been relatively little work done by regulators in this area to develop concrete techniques to quantify risks. Nevertheless, we consider that this option has a number of advantages that outweigh these limitations:

- It is consistent with economic principles since it takes account of the option value of investing in NGA;
- Application of an explicit premium is a more transparent approach to dealing with investment risks than ad hoc or implicit adjustments that cannot be tested;
- Failure to include such an allowance might result in allowed returns for operators that are lower than necessary to compensate for the risks and opportunity costs borne by investors, and this could disincentivise investment; and

- There are specific provisions for this approach in the EC Recommendation on the regulation of NGA networks and it is supported by precedent from some other European jurisdictions.[12]

Estimation of the NGA risk premium

Our review of European evidence suggests that there have been a few regulators that have made explicit allowance for a NGA risk premium. Furthermore, there is generally limited information on how estimates have been quantified. This is likely to be because the techniques required to quantify such a premium (i.e. real options analysis) can be very technical and regulators have yet to find a way of applying these readily.

The table below summarises the publicly available estimates of the NGA risk premium. It can be seen that these range from 1.8 to 3.5%. We note that the Dutch estimate is higher but this may be because it is older than the other two estimates and therefore likely to have been subject to more uncertainty. It is also unclear whether the Dutch estimate is real and pre-tax like the other estimates. Therefore, we propose using 2.5% as an estimate of the real pre-tax fibre risk premium.

12 EC September 2010 recommendation "Investment risk should be rewarded by means of a risk premium incorporated in the cost of capital."

Table 42. Publicly available estimates of the NGA risk premium

Source	Estimate	Description
Netherlands, OPTA (2008)	3.5%[13]	OPTA notes that the "fibre premium" is expected "to be higher when the investment begins but … to decline gradually" as uncertainty declines over time. However, OPTA did not specify how many years the fibre premium would apply or the underlying methodology and assumptions
Germany, BNetzA (2010)[14]	2.59%	Real pre-tax Unclear whether this has been applied yet
NERA (2011)[15]	1.8-2.5%	Real pre-tax Based on Monte Carlo simulation of real options model taking account of uncertainty in revenue per user and capex

Comparison with WACC estimates from other jurisdictions

In this section, we set out the WACC estimates from a range of European countries, EPT's estimate of its own WACC and our estimate for an efficient fixed network operator in Luxembourg. However, there are a number of reasons why it is difficult to compare headline WACC estimates from different countries. These are described in further detail below.

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13 OPTA did not provide an estimate of the NGA risk premium in its documents. The figure of 3.5% is from : "Regulatory policy and the roll-out of fibre-to-the-home networks", a report for the FTTH Council Europe, July 2012

http://www.ftthcouncil.eu/documents/Reports/Dot-econ_Regulatory_Report.pdf

14 "Wissenschaftliches Gutachten zer Ermittlung des kalkulatorischen Zinssatzes, der den spezifischen Risiken des Breitbandausbaus Rechnung trägt" 24 November 2010. http://www.bundesnetzagentur.de/SharedDocs/Downloads/DE/Sachgebiete/Telekommunikation/Unternehmen_Institutionen/Breitband/NGA_NGN/NGA_Eckpunkte/GutachtenProfStehle241110pdf.pdf?__blob=publicationFile&v=2

15 "A real options approach to estimate the risk premium for an FTTH investment", presentation to Infraday conference, 8 October 2011, Berlin

Limitations of comparing WACC estimates

Considering WACC estimates from European jurisdictions can provide some assurance that the estimate for Luxembourg is not significantly out of line with recent regulatory precedent. However, there are a number of reasons why any comparison of WACC estimates from different countries will provide limited insights. Some of these reasons are described below.

- Estimates are based on local data which are not necessarily comparable with operating conditions in Luxembourg (for example, because of different country specific risks). Such differences may be difficult to assess.

- Different regulators make different assumptions about taxes and inflation meaning that the headline WACC can be pre/post tax and real/nominal. This means that it is not possible to make direct comparisons between the headline WACCs allowed by different regulators. While it is possible to make adjustments to the WACCs so that they are all expressed on a common basis, this is typically an involved process. Further, this is difficult to explain and the adjusted numbers won't bear any resemblance to the numbers published in the original determinations.

- Not all regulators may be equally rigorous in their analysis, and their estimates may be derived at different points in time when operating conditions differ.

The figure below shows the pre-tax nominal WACC estimates for fixed networks in a range of European countries. We note that the ILR cost model uses real pre-tax WACC but this has been converted to a nominal WACC for ease of comparison. [16] For the same reason, we have also removed the NGA risk premium. It can be seen that the estimate for Luxembourg is towards the lost end of the range of the estimates in the sample of countries.

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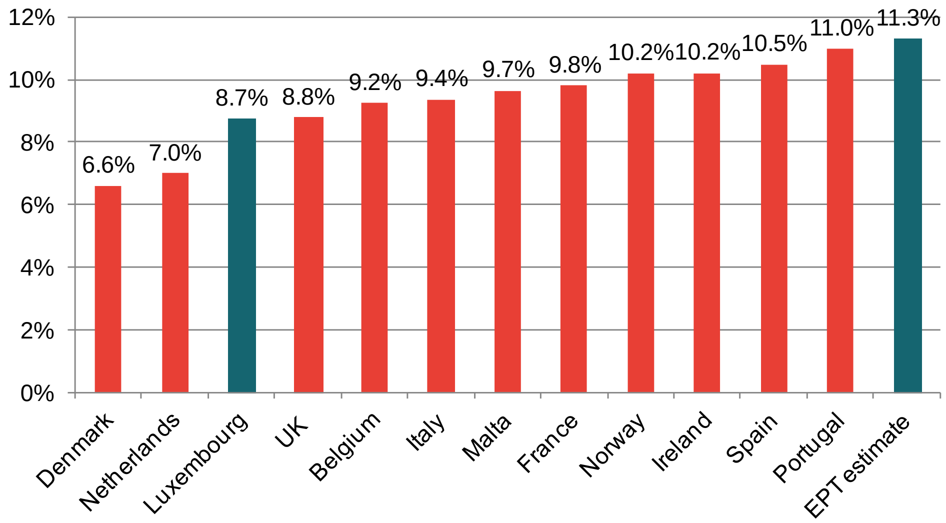
16 All estimates were pre-tax nominal except for the Netherlands and the UK which we adjusted for inflation.

Figure 13. Pre-tax nominal WACC estimates (excluding NGA risk premium)



Source: Various. Real WACCs for Netherlands and UK were adjusted using published inflation data

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- Malta: MCA (2012), Consultation and Proposed Decision on Estimating the Cost of Capital, September
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medio ponderado (WACC) de los operadores declarados con poder significativo de mercado por la Comisión del Mercado de las Telecomunicaciones, así como la estimación del WACC regulado para el ejercicio 2012 de los operadores obligados (MTZ 2012/1616)

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