AXON

Excellence in Business

Study on the financial and environmental impact of 5G and a fourth mobile network operator in Belgium

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1. Introduction

Axon Partners Group Consulting S.L.U. ("Axon") has been commissioned by the Belgian Institute for Postal Services and Telecommunications ("BIPT")[1] to carry out a study on the economic and environmental impact of 5G and the market entry of a 4th mobile network operator ("MNO") in Belgium.

The economic impact analysis should focus on investments and employment. For the environmental impact, we have been asked to examine, in particular, the expected effect on electromagnetic emissions, power consumption and electronic waste.

This study is structured as follows:

- **Section 2** provides an executive summary of the findings reached through this report in terms of economic and environmental impact of 5G and a 4th MNO.
- **Section 3** provides an outline of the Belgian mobile telecommunications market, with a comparison of its performance to that of other EU Member States and a brief description of its three MNOs' financials. This is followed by a description of the relevant NIR regulations, and an overview of available literature on the impact of a 4th MNO and 5G.
- **Section 4** includes an assessment of 5G's implications in Belgium, both from an economic (general and telecoms-specific) and environmental (radiation, power consumption, e-waste, various types of pollution) point of view.
- **Section 5** provides a high-level assessment of the operational feasibility and implications of a new MNO in Belgium. As in the previous section, this includes an analysis of such a new MNO entry's expected economic impact (directly on telcos and indirectly on the economy in general) and environmental implications in terms of electromagnetic radiation, power consumption, e-waste and various other types of pollution.

Axon thanks the BIPT and the Belgium's Federal Planning Bureau ("Bureau du Plan") for their support and contributions in the preparation of this report.

[1] Ref. n° 2021/SM/5GA EIE and 2021/SM/5GA EIS.

2. Executive Summary

2.1.1. **The Belgian telecoms market**

To set the context for our impact analysis, we have first compared the current performance of the Belgian mobile communications market to that of other EU Member States, relying on the European Commission's relevant DESI indexes. In relative terms, the score of Belgium is high for mobile coverage; above average for penetration (subject to a necessary correction to the statistic relied on by the European Commission); and below average for 5G readiness, mainly due to delays in the 5G spectrum auctions. For mobile broadband prices, the score is average for low-volume data allowance, but prices are higher than average for the larger data allowances.

In terms of the Belgian MNOs' financial performance, Proximus and Telenet have steadily enjoyed better EBIT and EBITDA returns than Orange. It is reasonable to assume this result may be at least partly due to their larger presence on the fixed market (with higher margins, which also appear to be linked to relatively higher fixed retail tariffs) and likely economies of scale and integration through fixed/mobile convergence.

The deployment of mobile access networks in Belgium may be constrained by the strict non-ionizing radiation ("NIR") limits imposed by each of the three Regions and particularly the Brussels Region – the latter are 50 times stricter than those recommended by the ICNIRP/EU. Moreover, and contrary to the emissions regime in the other two Regions, the Brussels standards apply cumulatively, for all technologies and frequency bands used by each mobile operator. Such strict NIR limits have contributed to 4G networks' near-saturation in several parts of Brussels. A rollout of 5G under the present emissions regime seems impracticable in Brussels, contrary to the two other Regions.

2.1.2. **Review of relevant literature**

We have reviewed recent literature on (i) the impact of the number of MNOs on mobile telecoms markets' performance, and (ii) the benefits and risks or obstacles associated with 5G.

Studies conducted by regulators generally suggest that the entry of a 4th MNO, with a disruptive business model, can be reasonably expected to lead to reduced mobile retail tariffs, at least in the short run (e.g., the first 1-2 years), in the range of 10-15% and possibly higher. The studies' conclusions on the impact of 3 vs. 4 MNOs on quality of service and investments are more ambiguous and remain subject to caveats. Factors such as the MNOs' operating margins or industry expectations on future profits may have a more significant impact on investment and hence also quality of service.

Earlier studies suggest that MNOs need at least a 20-25% market share for a minimum efficient scale. This may not necessarily be the case in a 5G environment, which involves different business opportunities (e.g., enterprise connectivity), niche use cases and potential revenue streams than those available under 4G.

According to literature, the main expected benefit of 5G is its role as an enabling technology for a range of other, independently developed, technologies (e.g., M2M/IoT, the cloud, AI etc.). These will, in turn, support and significantly improve existing services and applications, or create new ones. Thus, while the costs of 5G network rollout are expected to be considerable, industry analysts claim that these will be largely outweighed through the resulting direct and indirect benefits. It is expected that 5G can unlock high ICT-related revenues in Belgium as elsewhere, with benefits for a broad array of industries (e.g., healthcare, manufacturing, energy and utilities, automotive, public safety etc.).

One of the main, but so far hypothetical, risks discussed in 5G studies is its possible impact on human health and the environment, due to near-constant radiation from a potentially huge number of additional connections. Main obstacles to 5G adoption include continuing political and regulatory hurdles – with Belgian politics being identified as the root cause for delays and concerns relating to 5G. Further risks identified include 5G networks' potentially higher vulnerability to security breaches, and 5G's potential to create first-comer advantages that will widen economic gaps between countries and social groups.

2.1.3. **5G impact in Belgium**

Our impact analysis of a transition to 5G in Belgium has led to the following conclusions:

Economic impact of 5G

Despite uncertain key variables (number of networks deployed, NIR limits and other regulatory components, response of telcos and the industry etc.) the overall impact of 5G on the economy is expected to be fairly positive, even if the share of telcos in economic benefits from 5G remains uncertain and largely dependent on the strategy they will adopt.

Most reports reviewed estimate that 5G will annually contribute between 4 and 6 billion EUR to the Belgian economy (or 0.8% to 1.2% of GDP) by 2030. 5G is also projected to have a positive impact on employment – between 40,000 and 80,000 jobs by 2030, or an additional 1% to 2% to current employment figures -, almost entirely driven by developments in verticals using 5G rather than directly in the telecoms sector.

5G rollout in Belgium will require investments in the order of 1,5 bn EUR if Orange and Proximus operate under a RAN sharing agreement and favourable regulatory conditions, but up to 2,5 billion in a scenario of three access networks, under the current NIR limits. If the latter are changed in Brussels to the levels suggested by the BIPT, radiation exposure will be increased up to sixfold but still be about 88% below the INCIRP/EU recommended limits. In Flanders and Wallonia, under the existing regulations, 5G deployment should increase radiation exposure by about 33%, but this will still be well below the limits recommended by the ICNIRP and the EU (by 87% for Flanders[2] and 94% for Wallonia[3]). In all three Regions, a correction factor could be introduced to account for the lower average electric field resulting from the use of beamforming technology in 5G, without an increase in the overall electromagnetic radiations.

Environmental Impact of 5G

The telecoms sector's energy consumption in 2030 is broadly expected to be higher than today. However, and depending on the hypotheses adopted (mainly in terms of data traffic growth in the absence of 5G), the impact of 5G in 2030's energy consumption on the network side of the telecommunications sector could be up to 37% lower than compared to a situation without 5G on the Belgian market. On the other hand, even if 5G is expected to contribute to an increase in energy consumption on the user side of the telecoms sector, any quantitative estimate of this impact would be just a best guess with a wide margin of error.

We expect the impact of 5G on e-waste in Belgium to be negligible (less than 0.25% of the total), at least as regards the most directly affected sources of e-waste (network equipment, SIM-cards and devices). There are no systematic studies we are aware of quantifying reliably the wider impact on e-waste generation through the new use cases 5G is going to enable in the economy at large.

Thanks to massive reliance on renewables by MNOs in Belgium, any increase in energy consumption should not lead to a noticeable increase in GHG emissions in the country. However, as for e-waste, the potential impact on GHG emissions of the new use cases to be enabled by 5G remains largely uncertain.

2 If the new proposal of the Flemish Region (April 2021) to update the NIR limits is taken forward, the deployment of 5G would not have any impact on electromagnetic radiations in this Region (while these being 86% below the limits recommended by the ICNIRP and the EC).

3 Considering the ICNIRP thresholds at 900 MHz. The gap between the emissions and the ICNIRP's suggested limit would be broader if measured in higher frequency bands.

Visual, noise and air pollution impacts are all expected to be minimal, within the normal level of common public works.

2.1.4. **Operational feasibility and impact assessment for a new MNO in Belgium**

Economic feasibility and impact

Our analysis suggests that the most financially attractive scenario for a 4th MNO's entry in the Belgian market would involve a RAN sharing agreement with an existing MNO, and a background as an existing player in the broader telecoms market. In such a scenario, total market revenues could either grow or fall by around 5% by 2030, costs would likely increase by 5-15% in the long term, and mobile-related operating profits (for the sector as a whole) could decline by at least 40%[4], although the result could be better if spectrum sharing is allowed and the present NIR limits are relaxed.

New investments will be driven by 5G rollout and, in the aggregate, are unlikely to be affected significantly by the presence or absence of a 4th market entrant, be it in the short term (if the 4th MNO obtains a RAN sharing agreement) or in the long term (under any scenario).

The impact of the 4th MNO entry on employment is uncertain – as is the impact on revenues. However, at most, we expect it could lead to the generation or disappearance of up to 270 jobs in the telecoms sector and ± 220 jobs in other sectors of the Belgian economy by 2030.

These estimates should be considered against the broader, less direct, impact of a new MNO on the Belgian economy and society. We would expect an additional ±175 million EUR added to total national output by 2030, depending on the performance of the telecoms sector upon the entry of the 4th MNO. Further, we anticipate a positive annual contribution to consumer surplus of up to 350 million EUR (up to 14% of the mobile market's revenues) by 2030.

These figures would represent up to 1% of the economic benefits, investments and job generation expected through 5G and discussed earlier.

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4 The impact on profits at operator level may vary significantly. While the strongest may be well capable of resisting such a 40% decrease (and even, at least partially, compensate it through new use cases that 5G may enable), others may be brought into losses as a result of the 4th MNO entry.

Environmental impact

The impact of a 4th MNO entry on electromagnetic radiation will vary by Region. In the Brussels Region, if the NIR limits are increased upon the upcoming deployment of 5G, a 4th MNO will not exert any further impact on electromagnetic radiation (with these being 88% below the limits recommended by the ICNIRP and the EU). On the other hand, in the other two Regions a 4th MNO would likely result in an increase of electromagnetic radiation levels by 33%, although still quite below the limits recommended by the ICNIRP by ~87%[5] in Flanders and ~94% in Wallonia (83%[6] and 92% if considered altogether with 5G's expected impact)[7].

The entry of a 4th MNO could result in an increase of telecom networks' power consumption of up to 15%. Impact on e-waste should be negligible (close to 0%). Finally, the entry of a 4th MNO should have a negligible visual/aesthetic, noise, air pollution impact on the environment, i.e., not exceeding the common impact of public works, and on GHG emissions (potential increase of less than 0.03% of the total GHG emissions in Belgium).

2.1.5. **Conclusions**

Figure 2-1 below provides a summary of the expected impact in the economy of deploying 5G under the current market structure (i.e., with 3 MNOs) or in the event of a new 4th entrant:

5 81% if the recent proposal to update the NIR limits from the Flemish Region is taken forward.

6 81% if the recent proposal to update the NIR limits from the Flemish Region is taken forward.

7 Considering the ICNIRP thresholds at 900 MHz. The gap between the emissions and the ICNIRP's suggested limit would be broader if measured in higher frequency bands.

	Impact of 5G deployment		Impact of 5G deployment & a 4th MNO	
	Economy[1]	**Employment**[1]	**Economy**[1]	**Employment**[1]
Impact on the society	+4-6 bn EUR to annual GDP by 2030 **~1% GDP uplift**	+40-80k new jobs by 2030 **+1-2% jobs**[2]	+4-6 bn EUR to annual GDP by 2030 **~1% GDP uplift**	+40-80k new jobs by 2030 **+1-2% jobs**[3]
	Revenues	**Investment**	**Revenues**	**Investment**
Impact on the telecoms market	Traditional business **Mostly flat (=)** New use cases **Uncertain (up to 4%/year)**	**1.0 bn EUR**[4] **up to 2.5 bn EUR**	Traditional business **From -5 to 5%**[5] New use cases **Uncertain (up to 4%/year)**	**1.0 bn EUR**[4] **up to 2.5 bn EUR** (Lower investment per MNO, same total overall)

Figure 2-1: Economic impact of 5G deployment with and without a 4th MNO [Source: Axon]

(1) These include the additional output and employment in the telecoms sector and the overall national economy. Most of this impact will actually come from sectors other than telecom (e.g., healthcare, automotive, transport, utilities).
(2) These jobs will be mostly driven by developments in verticals that make use of 5G rather than directly in the telecoms sector itself through traditional services and operations, where no relevant long-term impact on employment is foreseen. The impact on employment in the telecoms sector will be highly dependent on operators' ability to innovate and/or vertically integrate.
(3) The entry of a 4th MNO is not expected to have a significant impact on employment, either at national level or in the telecoms sector. Based on our estimates, up to around 270 jobs could appear/disappear in the telecommunications sector, and up to 220 jobs could appear/disappear in other sectors with the entry of a 4th MNO by 2030.
(4) Related to the deployment of two 5G access networks and under favourable regulatory conditions.
(5) A consumer surplus of up to 350 million EUR/year may be generated.

In summary, while 5G is expected to have a highly positive impact on the economy, the impact of a 4th MNO is going to be mostly limited to the consumers and operators of the telco sector.

Additionally, the deployment of 5G is expected to have some implications for the environment. As Figure 2-2 below shows, 5G and the presence of a new entrant are likely to lead to higher non-ionising radiations – although still at levels much lower than those allowed in most of the EU – and an expected decrease in energy consumption (compared to a scenario where 5G was not deployed). Nevertheless, none of the projected impacts on environment are expected to be significant.

	Impact of 5G deployment	Impact of 5G & a 4th MNO
Electromagnetic radiation	***Brussels:*** *+6x if NIR limits are relaxed[1].* ***Flanders/Wallonia****: +33%[3].* *In both cases, still ~80-90% below ICNIRP's suggested limits[5]*	***Brussels:*** *+6x if NIR limits are relaxed[2].* ***Flanders/Wallonia****: +78%[4]* *In both cases, still ~80-90% below ICNIRP's suggested limits[5]*
Energy consumption	***Network:*** *From -37% to -1% by 2030[6]* ***End-devices****: Likely but uncertain increase by 2030*	***Network:*** *From -22% to +14% by 2030[6]* ***End-devices****: Likely but uncertain increase by 2030.*
E-waste	***Negligible direct impact by 2030 (<0.25%)*** ***Uncertain indirect impact by 2030***	***Negligible direct impact by 2030 (<0.25%)*** ***Uncertain indirect impact by 2030*** *(No material contribution of the 4th MNO on e-waste)*
Visual/aesthetic, noise, air pollution, GHG emissions	***Negligible impact by 2030***	***Negligible impact by 2030***

(1) Assuming the NIR limits are increased in the Brussels Region to 14.5 V/m (i.e. to the minimum level proposed by BIPT in its report from 12 September 2018).
(2) Assuming the NIR limits are increased in the Brussels Region to 14.5 V/m (i.e. to the minimum level proposed by BIPT in its report from 12 September 2018) and that 25% of these limits are assigned to each MNO.
(3) If the recent proposal of the Flemish Region (April 2021) to update the NIR limits is taken forward, the deployment of 5G would not have any impact on electromagnetic radiations in this Region.
(4) If the recent proposal of the Flemish Region (April 2021) to update the NIR limits is taken forward, the cumulative impact on electromagnetic radiations of deploying 5G and having a 4th MNO in the mobile market would be of +33% in this Region.
(5) Considering the ICNIRP thresholds at 900 MHz. The gap between the emissions and the ICNIRP's suggested limit would be broader if measured in higher frequency bands.
(6) 2030 comparison of energy consumption with and without 5G deployment. Based on a 4G data traffic increase (in the absence of 5G) of between 3x and 5x by 2030.

Figure 2-2: Environmental impact of 5G deployment with and without a 4th MNO [Source: Axon]

3. Context

To set the context for our impact analysis, we shall first recapitulate the current situation of the Belgian telecommunications market, with special focus on its mobile segment. This overview will compare the performance of the Belgian mobile market to that of other EU Member States in terms of the DESI mobile broadband index (Subsection 3.1.1) and mobile broadband retail prices (Subsection 3.1.2), and discuss likely causes of any low scores for Belgium. This will be followed by a brief discussion of the current financial performance of Belgian MNOs in Subsection 3.1.3, and international/domestic regulation of electromagnetic radiation (Subsection 3.1.4), a key parameter in the context of the whole 5G debate, and a constraint in the context of a new mobile market entry.

To complete the backdrop of this study, we then summarize the findings of recent literature and other sources of reference relating to mobile market structure (Subsection 3.2), and the benefits and risks associated with 5G (Subsection 3.3).

3.1. Situation of the Belgian telecommunications market

3.1.1. Comparative overview of the performance of the Belgian mobile market

For utmost objectivity, our comparative analysis of the performance of the Belgian mobile market relies on the metrics of the "**Digital Economy and Society Index**" (**DESI**) developed by the European Commission ("**EC**").

DESI is a composite index, calculated from relevant indicators of Europe's digital performance, which tracks the evolution of EU Member States' digital competitiveness. As such, it provides an objective overview of country-based KPIs, and therefore an ideal measurement tool for juxtaposing KPIs of the Belgian mobile market against those of other EU Member States. It also facilitates comparisons between groups of national markets, such as those with three MNOs vis-à-vis those with 4 or more MNOs. DESI indicators also offer insights into key areas of success or failure of a telecommunications market, and can therefore assist in a high-level market diagnosis, highlighting areas that require deeper analysis.

To recapitulate, DESI consists of five main components (connectivity, human capital, use of Internet services, digital technology integration, and digital public services), each of which includes a number of sub-components and individual indicators. For the sake of this study, we will concentrate solely on one of these components, **Connectivity**, as this will provide the most relevant information on the performance of the Belgian telecoms market**.**

The Connectivity component of the DESI is structured as shown in the table below. Indicators directly related to mobile networks and discussed in this analysis are highlighted in green.

	Sub-component	Indicators and their relative weight
Connectivity	1a Fixed broadband adoption	1a1 Overall fixed broadband adoption rate (50%)
		1a2 At least 100 Mbps Broadband adoption (50%)
	1b Fixed broadband coverage	1b1 Broadband coverage (NGA) (50%)
		1b2 Very high-capacity fixed network coverage (VHCN) (50%)
	1c Mobile broadband	1c1 4G coverage (25%)
		1c2 Mobile broadband adoption (25%)
		1c3 5G readiness (50%)
	1d Broadband price	1d1 Broadband price index (100%)

Table 3-1: Structure of the connectivity component of the DESI [Source: EC, Digital Economy and Society Index (DESI) 2020 - Thematic Chapters]

The Connectivity component is more relevant to the purposes of this study, since a country's performance in this category is primarily linked to its telecoms market structure and the performance of its operators rather than to any exogenous or broader economic, societal, social or public policy factors, which are beyond the sphere of influence of the telecommunications industry and the scope of this study. Therefore, the contribution and importance of the three Belgian MNOs to national connectivity can be assessed more meaningfully based on indicators relating to connectivity, and in particular those sub-indicators related to mobile broadband (sub-dimension 1c) compared to those of the EU28.

The results of these indicators are provided below:

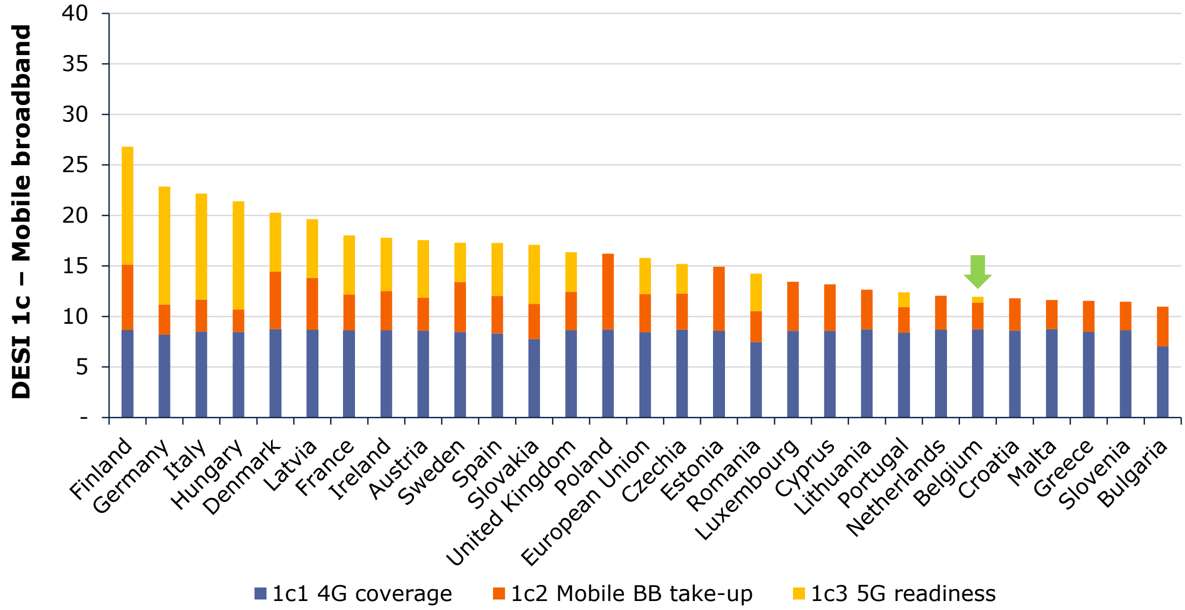

Figure 3-1: DESI mobile broadband index by country – 2020 [Source: EC]

As Figure 3-1 shows, Belgium is currently placed near the bottom of the DESI list across the three mobile-related subdimensions. However, before drawing any rush conclusions, it is helpful to break down this result into its three individual indicators to identify the main area(s) for improvement:

Rank	1c1 4G coverage	1c2 Mobile BB take-up	1c3 5G readiness
Belgium	4/28	26/28	17/28

Table 3-2: Belgium's rank in mobile-related DESI Connectivity indicators – 2020 [Source: EC]

From this breakdown we are able to diagnose the causes of Belgium's seemingly low mobile score:

Coverage

With respect to subdimension 1c1 (4G coverage), Belgium's coverage levels are amongst the highest in Europe meaning, clearly, that the country is not underperforming in this area.

Take-up

Mobile broadband take-up is rather low, with Belgium holding the third lowest ranking for this subdimension. However, as confirmed by BIPT, this apparently weak performance is driven by an issue in the reporting of the information to the EC, which has underestimated mobile broadband take-up in the country by 10-15%. If these figures are corrected, Belgium's ranking would improve by several places, leading to an above-average score for this indicator.

5G readiness

According to the EC's explanatory remarks, the points allocated to this indicator are based on "*the amount of spectrum assigned and ready for 5G use by the end of 2020 within the so called 5G pioneer bands. These bands are 700 MHz (703-733 MHz and 758-788 MHz), 3.6 GHz (3400-3800 MHz) and 26 GHz (1000 MHz within 24250-27500 MHz). All three spectrum bands have an equal weight.*"

5G readiness is therefore an obvious driver of Belgium's low mobile-related score, and can be attributed to the delay in the country's 5G spectrum auction(s). According to public reports, the auction for 700 MHz and 3.6 GHz spectrum is expected to take place only in 2022. Once these bands are assigned, Belgium's score for this subdimension should rise and it should get back on track with its EU peers. However, the situation with regard to the 26 GHz band would still be uncertain: although it is taken into consideration as part of the DESI 5G readiness indicator, a public consultation carried out in 2019 by the BIPT[8] revealed a lack of demand for this spectrum in Belgium.

Conclusions

Summing up, we can conclude that Belgium has performed well in terms of mobile coverage (DESI indicator 1c1), and (subject to a correction of the statistics shared with the EC), mobile broadband take-up (DESI indicator 1c2). However, the continuing delay in the auction of 5G spectrum has resulted in a low score for Belgium's 5G readiness (DESI indicator 1c3).

3.1.2. **Comparative overview of mobile broadband retail prices**

While DESI does not provide a clear comparison in terms of mobile broadband retail prices across EU Member States, the European Commission's "Mobile and fixed broadband prices in Europe at the end of 2019" report[9] allows for an unbiased and consistent comparison of mobile broadband retail prices in the European Union. The figure below summarises the outcomes reached in that report, showing that Belgium's mobile broadband retail prices fall around the EU average:

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8 *Consultation on the use of the 26 GHz band for 5G.*

9 Available here.

	0,5GB mobile data with no calls	1GB mobile data with no calls	2GB mobile data with no calls	5GB mobile data with no calls	20GB mobile data with no calls	0,5GB mobile data with 30 calls	1GB mobile data with 30 calls	2GB mobile data with 100 calls	5GB mobile data with 300 calls	20GB mobile data with 300 calls	5GB mobile data with 30 calls	20GB mobile data with 100 calls
RO	1	1	1	1	1	1	1	1	1	1	1	1
SE	1	2	2	1	2	2	1	1	1	2	1	1
AT	3	2	2	1	1	2	1	2	1	2	1	1
DE	1	1	2	2	2	1	1	2	2	2	2	2
EE	2	1	2	2	2	1	2	2	1	2	1	2
IT	3	2	2	1	1	3	2	2	1	1	1	1
UK	3	2	2	2	1	2	1	2	1	2	1	1
FR	3	2	2	2	1	2	2	3	1	1	1	1
LU	1	1	2	1	4	2	1	1	1	3	1	3
PL	3	3	2	2	1	3	2	2	1	1	1	1
SI	3	2	2	2	1	2	1	2	2	2	2	1
FI	1	2	3	2	1	2	2	3	2	2	2	1
NL	3	2	3	2	1	2	1	3	2	2	1	1
BG	2	1	1	2	2	1	1	3	3	3	3	3
BE	1	1	2	3	3	3	2	2	2	3	2	3
LV	2	1	2	1	1	3	3	3	2	3	3	3
DK	4	3	3	2	1	3	3	3	1	2	2	1
HR	1	1	2	2	2	3	2	2	3	4	2	4
MT	2	3	2	1	4	1	2	3	2	4	2	4
EL	2	1	1	2	2	3	2	4	3	4	3	4
LT	4	3	4	3	2	3	3	3	2	2	2	2
ES	3	3	3	2	2	3	3	4	3	3	2	3
HU	1	1	2	3	4	2	2	4	4	4	3	4
IE	4	4	4	3	2	4	4	3	2	2	2	1
PT	3	2	4	3	2	2	4	4	3	3	3	4
SK	4	3	4	3	3	3	3	4	4	4	4	4
CY	3	4	4	4	4	3	4	4	4	4	4	4
CZ	3	3	4	4	4	4	4	4	4	4	4	4

Cluster Centres [EUR]

1	4.18	5.2	5.58	8.36	13.11	5.55	7.44	6.64	11.35	11.31	11.13	14.99
2	6.08	8.64	9.25	12.76	22.65	8.72	11.86	10.91	17.78	19.62	15.81	24.84
3	9.36	11.73	13.12	17.72	32.39	12.21	14.31	15.65	28.2	38.04	23.65	35.46
4	14.15	20.14	18.46	31.56	45.27	19.88	20.18	25.63	39.84	60.15	35.14	57.34

Number of cases in each cluster

1	8	10	3	7	11	5	9	3	10	4	10	12
2	5	9	15	13	10	10	10	9	9	11	10	3
3	11	7	4	6	2	11	5	9	5	6	5	5
4	4	2	6	2	5	2	4	7	4	7	3	8

Green symbol 1 – inexpensive cluster
Blue symbol 2 - relatively inexpensive cluster
Yellow symbol 3 – relatively expensive cluster
Red symbol 4 – expensive cluster

Figure 3-2: Price performance per offer category across the EU, country clusters - Mobile broadband [Source: EC]

Individual tariffs seem to be broadly aligned with the EU average, especially for the smaller price baskets, although Belgium's position is lower for the higher-end bundles, as illustrated below.

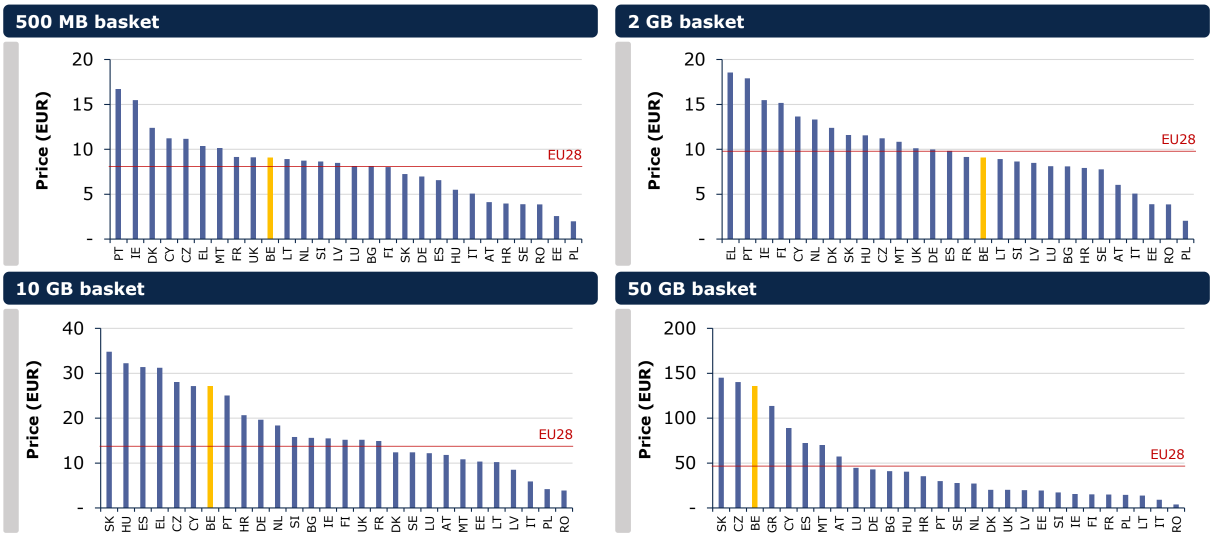

Figure 3-3 : Mobile data basket rates [Source: EC]

As illustrated by these figures, Belgian consumers pay average EU prices for low-volume data allowances. However, for large data allowances (e.g., 50GB per month), Belgian consumers can find offers priced at more than twice the EU average.

As a next step, it is worth exploring whether such price performance may be the result of Belgian MNOs applying higher margins than the EU average or if these are likely driven by higher costs of providing the service.

We have first compared Orange's financial results, as the only Belgian network operator with over 60% of its revenues coming from the mobile segment, in terms of EBIT and EBITDA (see section 3.1.3), with those of other EU MNOs which also receive over 60% of their revenues from the mobile segment. The figure below shows the results of this comparison for the financial years 2019 and 2020:

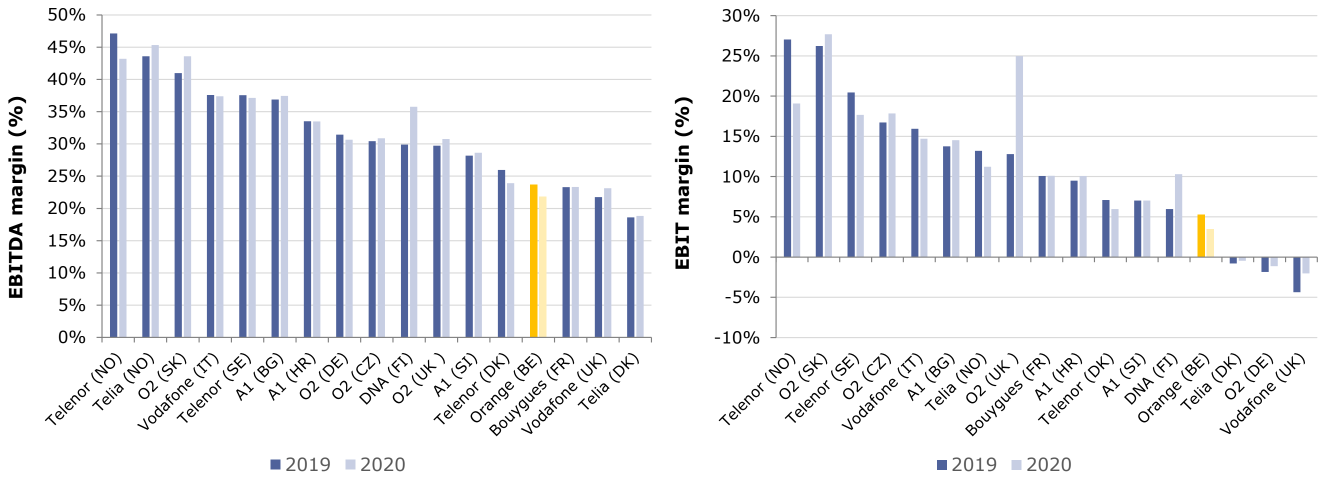

Figure 3-4: EBITDA and EBIT margins of EU network operators with over 60% of their revenues coming from the mobile segment [Source: Axon]

This comparison suggests that, at least in the case of Orange, its retail price performance is unlikely to be driven by higher profit margins than the EU average.

Additionally, we have explored the cost-related information made available by the European Commission (EC) as part of its study on mobile network costs in the EU.[10] This is the only reference we are aware of that provides recent cost-related information for all EU Member States. Despite results fluctuating over the years, reports made available by the EC consistently place Belgium in the top quarter of countries with the highest costs. These findings could reinforce the argument that retail price performance in Belgium is unlikely to be driven by higher profit margins than the EU average, but rather by higher-than-average costs.

Unfortunately, the BIPT and Axon could only access the detailed cost calculations carried out by the EC for Belgium, but not those for the other EU Member States. Hence the factors driving Belgium's higher-than-average costs – at least according to the EC's reports – remain unknown, which diminishes the relevance of these findings.

3.1.3. **Financial situation of the Belgian MNOs**

The Belgian market is served by three MNOs: Proximus, Orange and Telenet (BASE). Between them, these three players share around 10.7MM subscribers, across both the

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10 Finalisation of the mobile cost model for roaming and the delegated act on a single EU-wide mobile voice call termination: SMART 2017/0091 | Shaping Europe's digital future (europa.eu)

prepaid and postpaid segments, with a combined market size of €2.1 Bn.[11] As of 2019, the market leader, Proximus, has a revenue-based market share of 45.5%, far ahead of the competitors, with 27.8% for Orange, 21.3% for Telenet and 5.4% for MVNOs. Proximus market leadership is largely driven by its share of postpaid subscribers. The overall mobile market HHI[12] is roughly 3,500[13] for the MNOs alone, or about 3,300 including MVNOs.

As in many countries around the world, the Belgian mobile market is witnessing a mostly flat trend in its subscriber base, combined with slow growth in revenue.

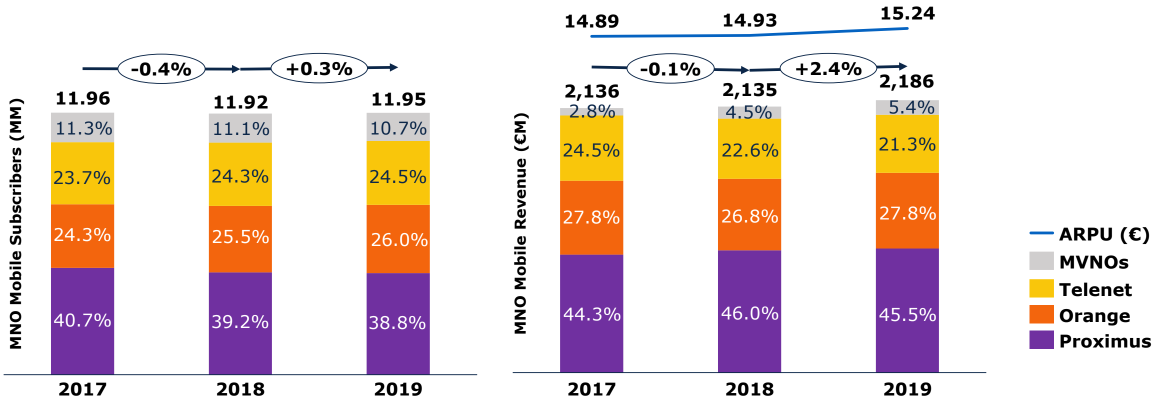

Figure 3-5: Mobile Subscriber and Revenue growth [Source: BIPT]

On an individual basis, there is a noticeably high variation in the financial make-up among the different players. Based on the MNOs' wider activity, overall EBIT and EBITDA margins vary greatly across the market. The Figure below details this variation in EBITDA and EBIT for the three MNOs:

11 BIPT, Mobile Belgium Market Shares, 2019 data

12 HHI (Herfindahl-Hirschman Index) is the sum of the squares of each MNO's market share. Higher figures indicate less competition. The maximum value of HHI (i.e., a full monopoly) is 10,000.

13 An HHI higher than 2,500 is typically considered to represent a highly concentrated marketplace, a common feature in most mobile telecommunications markets. In particular, Belgium's HHI of 3,500 (without MVNOs) is aligned with the average HHI in EU Member States with three MNOs (3,470) and is above the average HHI in EU Member States with four MNOs (2,890).

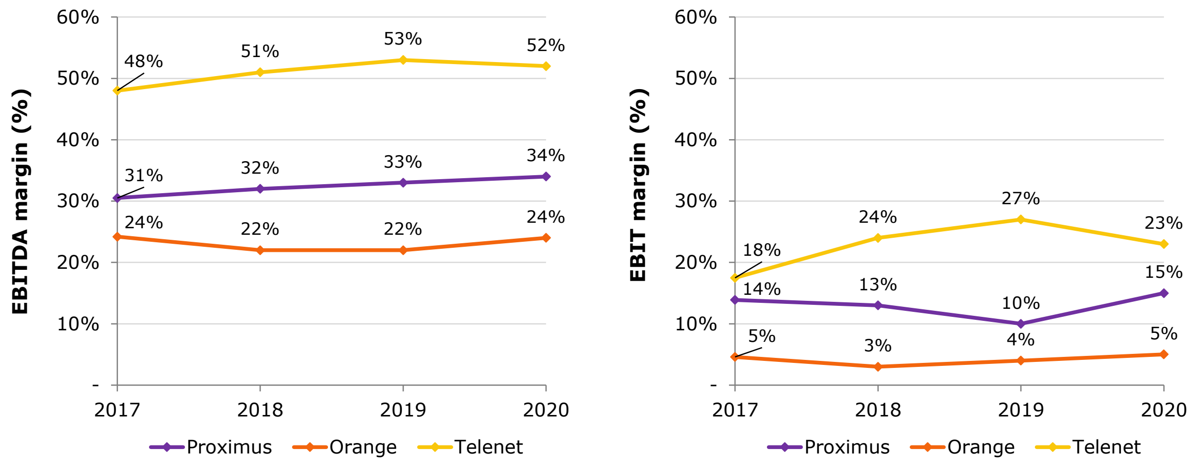

Figure 3-6: MNOs' Financials [Source: MNOs financial statements]

Interestingly, Proximus and Telenet, both with much larger non-mobile market revenues, have steadily enjoyed better returns in terms of EBIT and EBITDA than Orange, who is mostly focused on the mobile segment. Overall, the situation may be potentially driven by different variables, for instance:

- Higher margins in the fixed segment, which could also explain Belgium's higher prices as compared to the EU average.
- The economies of scale gained by Proximus and Telenet, thanks to convergence between their fixed and mobile networks.

3.1.4. **Regulation of electromagnetic radiation**

International regulation

Electromagnetic field (EMF) radiation can be classified as **ionising**, if it has sufficient energy to produce ionisation in molecules and atoms, and **non-ionising**. Non-ionising radiation carries lower levels of energy, and has lower frequencies and longer wavelengths than ionising radiation. The exact boundary between the two types of radiation is not sharply defined, as different molecules and atoms ionize at different energies. It is clear, however, that all electromagnetic radiation emitted by 5G networks' base stations and terminal equipment (cellphones) qualifies as non-ionising radiation.

While it is well-established that ionising radiation has enough energy to damage DNA and cause cancer and other damage to human health, the health risks, if any, associated with exposure to non-ionizing radiation are a matter of continuing scientific debate and evolving rules and regulations.

There is no legally binding EU regulation of the allowed exposure of the public at large to non-ionising radiation, as the competence for setting any such exposure limits and their implementation lies with the EU Member States, in line with **Article 168 TFEU**.[14] In place of any legally binding rules, **Council Recommendation (1999/519/EC) on the exposure of the general public to electromagnetic fields**[15] recommends emission limits based on guidance issued, at the time, by the **International Commission on Non-Ionizing Radiation Protection (ICNIRP)**. **Article 58 of the European Electronic Communications Code** (EECC) requires EU Member States to (simply) notify the European Commission of any draft measures they intend to adopt that would impose on the deployment of small-area wireless access points different requirements with respect to electromagnetic fields than those provided for in Council Recommendation 1999/519/EC. The EECC contains various other references to this Recommendation, but none of these gives rise to mandatory standards for EU Member States.

In March 2020, the ICNIRP published updated "**Guidelines for Limiting Exposure to Electromagnetic Fields (100 KHz to 300 GHz)**".[16] These new Guidelines, which are not radically different on substance from their earlier version, have been adopted following a review of scientific data on the effects of exposure that can be considered to be both adverse to humans and scientifically substantiated. The only adverse health effects considered for these purposes have been (i) nerve stimulation (up to about 10 MHz) and (ii) heating (from about 100 kHz). (According to the ICNIRP, in the studies reviewed, no scientific evidence was found to exist for cancer, electrohypersensitivity, infertility or other health effects.) A minimum exposure level needed to produce adverse health effects has been defined, and has then been subject to a "reduction factor" for workers and a larger one for the general public, in order to recommend exposure restriction limits with a large margin of safety.

It should be noted that as frequencies increase, exposure of the body and the resultant heating becomes more superficial. By contrast, the lower the frequency, the higher the absorption. Therefore, the standards for lower frequencies are generally stricter. Above about 6 GHz, any such heating occurs predominantly within the skin. However, as stated

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14 See, for example, the answers given by the Commission to Parliamentary questions in 2020 and 2018. On the other hand, given its more broadly defined powers to introduce social policy legislation, the EU has adopted Directive 2013/35/EU "on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields)".

15 Council Recommendation 1999/519/EC of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz), OJ L 199, 30.7.1999, p.59.

16 Available here.

in the ICNIRP Guidelines, to err on the side of caution, the ICNIRP has set equal whole-body average limits for frequencies both above and below 6 GHz.

ICNIRP's proposed restrictions fall into two categories: (i) "basic restrictions", which refer to fields in people (ultimately what such a health measure should be about) but cannot be measured easily, and (ii) "reference levels", which refer to fields in the environment and can be measured more easily. A similar distinction, taken from the earlier ICNIRP Guidelines, can be found in Council Recommendation 1999/519/EC.[17]

An overview of the ICNIRP Guidelines' "basic restrictions" is shown in the Table below:

Basic restrictions

Parameter	Frequency range	ΔT	Spatial averaging	Temporal averaging	Health effect level	Reduction factor	Workers	Reduction factor	General public
Core ΔT	100 kHz-300 GHz	1°C	WBA*	30 min	4 W/kg	10	0.4 W/kg	50	0.08 W/kg
Local ΔT (Head & Torso)	100 kHz-6 GHz	2°C	10 g	6 min	20 W/kg	2	10 W/kg	10	2 W/kg
Local ΔT (Limbs)	100 kHz-6 GHz	5°C	10 g	6 min	40 W/kg	2	20 W/kg	10	4 W/kg
Local ΔT (Head & Torso, Limbs)	>6-300 GHz 30-300 GHz	5°C	4 cm^2 1 cm^2	6 min 6 min	200 W/m^2 400 W/m^2	2	100 W/m^2 200 W/m^2	10	20 W/m^2 40 W/m^2

* WBA: whole body average

Table 3-3: Basic restrictions under ICNIRP 2020 Guidelines [Source: ICNIRP]

"**W/m^2**", i.e., Watts per square metre are used to measure **power density (S)** or (power flux density). Power density is a function of the **electric field strength (E)** (which is expressed by **V/m**, Volt per meter), as follows:

$$\text{Power density} = (\text{Electric Field})^2 / 376{,}73$$

"**W/kg**", i.e., Watts per kg, is the unit measuring the rate at which energy is absorbed per unit mass of body tissue.

17 Under this Council Recommendation, "basic restrictions" are defined as "restrictions on exposure to time-varying electric, magnetic, and electromagnetic fields which are based directly on established health effects and biological considerations". "Reference levels" are defined as levels "provided for practical exposure-assessment purposes to determine whether the basic restrictions are likely to be exceeded."

The Exhibit below shows an example (general public, whole body, ≥ 6 minutes) of the reference level restrictions under ICNIRP's new Guidelines. The years shown in the Exhibit ("1998", "2010" and "2019") refer to those of the relevant ICNIRP's Guidelines adoption (with 2019 actually standing for 2020, year of the most recent adoption).

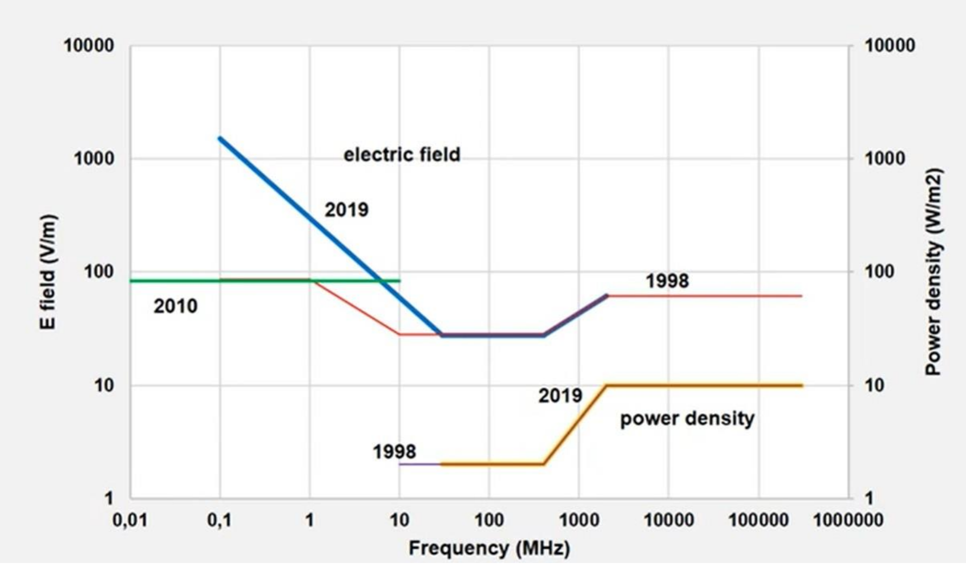

Figure 3-7: Example of Reference Restrictions [Source: ICNIRP]

While the adoption of the revised ICNIRP Guidelines in 2020 is expected to lead to adjustments to Council Recommendation 1999/519/EC, the applicable restrictions in terms of NIR limits should remain broadly unchanged.

For now, it can be assumed that any such near-term adjustments to the 1999 Council Recommendation are unlikely to affect materially the current European institutional framework for health-related measures linked to electromagnetic radiation. Member States will thus retain the legal power to define exposure limits for the protection of the public at large.

Belgian Regulation

The Constitutional Court has confirmed that the adoption of standards against any risks associated with non-ionising radiation falls within the competence of the Regions, as part of the general regulatory powers regarding environmental protection.[18] In line with this division of competence, each Region has adopted its own set of rules on emission limits. These are summarized in an BIPT study of 12 September 2018 "on the impact of the

[18] Decision nr. 2/2009 of 15 January 2009.

radiation standards in Brussels on the deployment of mobile networks",[19] and are recapitulated in below, for easy reference. In all relevant measures, "*f*" represents the frequency in MHz.

Region	Relevant legislation	Description
Brussels-Capital Region	Ordinance of 1 March 2007 on the protection of the environment against any harmful effects and nuisance caused by non-ionising radiation (available here); Decree of the Government of the Brussels-Capital Region of 30 October 2009 on certain antennas emitting electromagnetic waves (available here); Decree of the Government of the Brussels-Capital Region of 8 October 2009 laying down the methodology and terms for measuring the electromagnetic field emitted by some antennas (available here); Ministerial Order of 30 June 2010 concerning the validation of a simulation tool calculating the electric field emitted by an antenna emitting electromagnetic waves (available here);	Cumulative limits as follows: 0.043 W/m² for 0.1 - 400 MHz; f/9375 W/m² for 400 MHz - 2 GHz; 0.22 W/m² for 2 GHz - 300 GHz. All the antennas of an operator may not exceed 33% of the cumulative limit in zones accessible to the public.
Flemish Region	Decree of the Flemish Government of 1 June 1995 laying down the general and sector-bound provisions regarding environmental hygiene (VLAREM II, available here)	Cumulative limits (average, measured over 6 minutes) as follows: 13.7 V/m for 10 - 400 MHz; 0,686 √f V/m for 400 MHz - 2 GHz; 30.7 V/m for 2 GHz - 10 GHz In addition, each antenna of an operator may not exceed 3 V/m at 900 MHz. This corresponds to 2.125% of the cumulative limit and is the most restrictive limit in practice, for up to 47 antennas.

[19] As mentioned in its introductory part, the study was prepared in response to letters the BIPT received in 2018 from the Vice-Premier and Minister in charge of telecommunications, and the Minister for the Environment.

Region	Relevant legislation	Description
Walloon Region	Decree of 3 April on the protection against harmful effects and nuisance caused by non-ionising radiation generated by stationary transmitting antennas (available here).	3 V/m for each antenna, regardless of the frequency, as an average value calculated and measured over any period of 6 minutes and over a horizontal area of 0.5 x 0.5 m2. These limits apply per antenna, and not for all antennas in a given location, and concern all living areas, such as homes, offices, schools, hospitals, sports grounds, etc.), but not, e.g., garages, balconies and terraces, and outdoor areas.

Table 3-4: Rules on EMF emissions in the three Regions [Source: BIPT and relevant legal texts]

The above radiation standards in the three Regions are generally much stricter than those recommended by the ICNIRP and, by extension, the EC. The map below[20] provides a high-level comparison of the policy followed in Belgium to those adopted by other EU Member States. (Please note, however, that contrary to the indications in this, slightly outdated, map, we understand that, in 2020, both Poland and Lithuania have replaced their more restrictive limits with EMF limits based on the ICNIRP guidelines.[21])

[20] Available here.

[21] See https://www.gsma.com/publicpolicy/authorities-should-lead-in-addressing-5g-emf-misinformation.

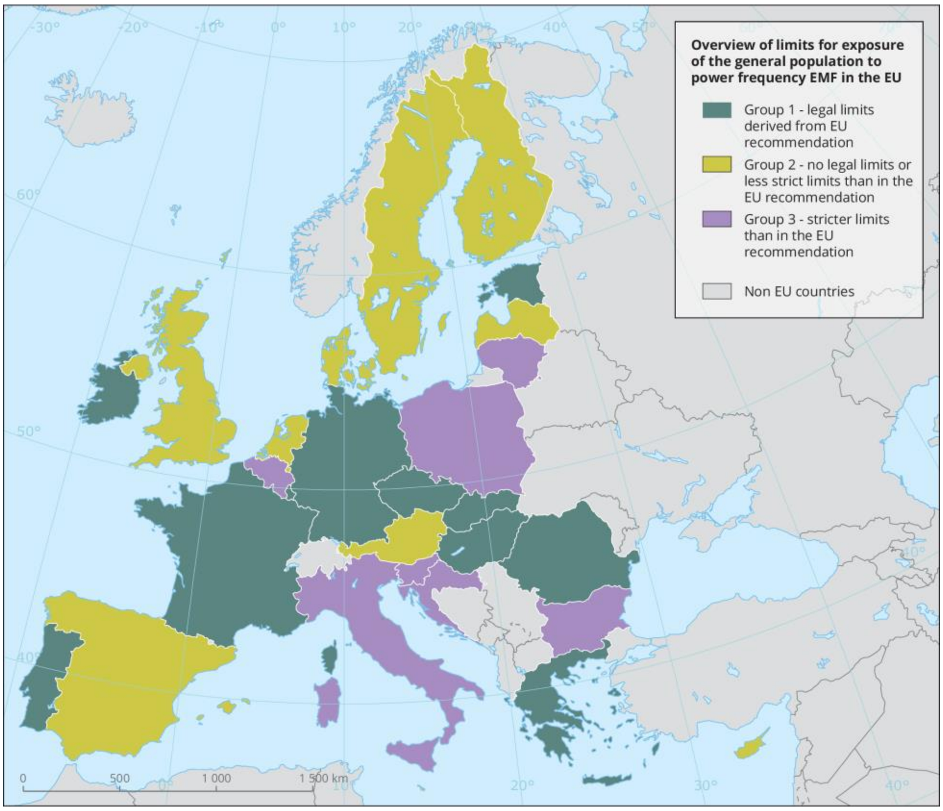

Figure 3-8: Overview of EMF exposure limits in the EU [Source: European Environment Agency]

In its study of 12 September 2018 "on the impact of the radiation standards in Brussels on the deployment of mobile networks", the BIPT has provided a visual comparison of radiation limits (at 900 MHz) in different EU Member States to those in Brussels. The data used were based on the 2018 "Comparison of international policies on electromagnetic fields", prepared by the Dutch National Institute for Public Health and the Environment.

As shown in the Figure below, limits in place in Brussels are almost 50 times lower than those recommended by ICNIRP and the EC, and also applicable (directly or in the absence of any national limits) to most of the EU Member States.

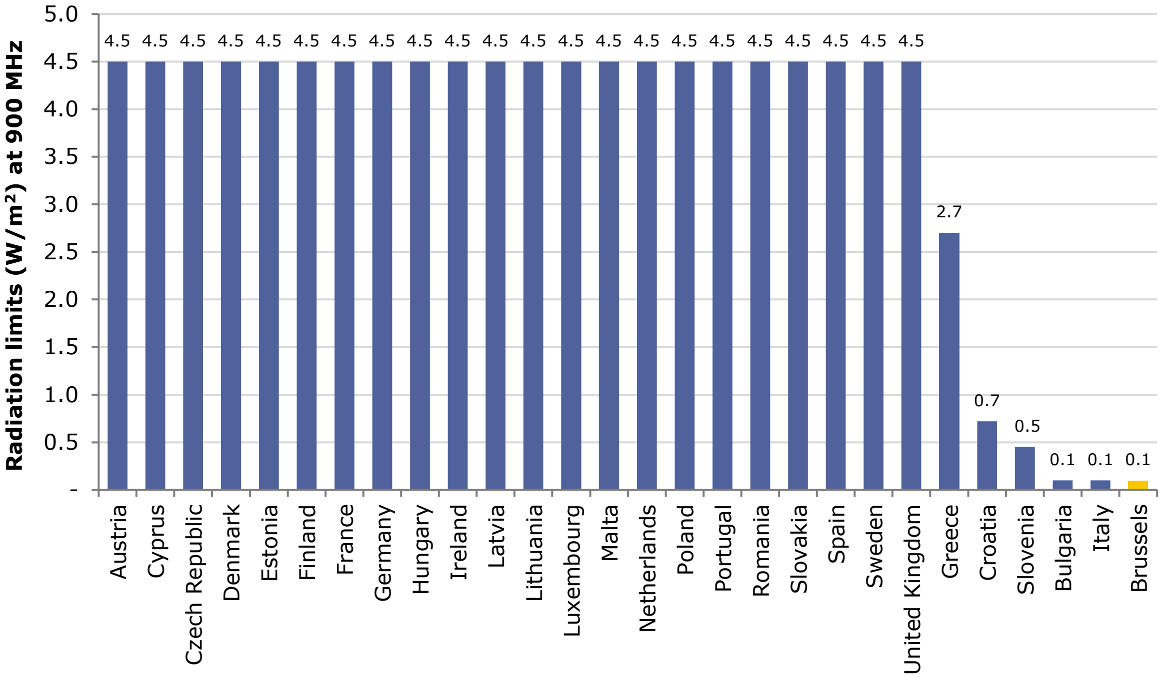

Figure 3-9: Comparison of radiation limits (900 MHz) in the EU [Source: BIPT and Axon]

More generally, it is difficult to draw exact comparisons between different Member States and even between the three Regions in Belgium, as a lot depends on the number of operators, technologies and frequency bands used, population density, volume of traffic and resultant mobile network capacity needs, etc. Subject to these caveats, a comparison between the three Regions has been undertaken by the BIPT in its study of 12 September 2018 (esp. its Annex 1). To recapitulate, the comparison's general conclusion was that, "[f]*or the deployments of the current mobile networks, the radiation standards in Brussels are 4 times more stringent than the Flemish standards and 2 times more stringent than the Walloon standards. For the deployment of the mobile networks planned after 2020, the radiation standards in Brussels will be 7 times more stringent than the Flemish standards and more than 2 times more stringent than the Walloon standards*."

The study also found that radiation standards in Brussels were almost 50 times stricter than what was recommended by the ICNIRP and the European Union. This remains the case after the ICNIRP's adoption of its 2020 Guidelines.

Impact of EMF emission standards on 5G rollout prospects

Strict EMF emission standards require lower powered individual antennas and hence a larger total number, thus increasing the cost of network rollout, especially as obtaining additional antenna sites is an increasingly complicated process for the operators, as the number of available sites has diminished substantially with the rollout of the existing mobile networks. Moreover, the risk of a saturation of mobile networks, even with a few extra sites, may be an even worse problem in light of the explosive growth of mobile data traffic in recent years, a process likely to be accelerated.

The risk of mobile network saturation in Belgium and its link to strict emission limits have been discussed in a very recent communication of the BIPT on the "risks of saturation of mobile networks".[22] The study focused on the existing 4G networks in Brussels, Antwerp and Liège and concluded that the risks of 4G network saturation differ substantially between the three cities studied, mainly due to their different electromagnetic radiation standards.

Of the three cities, Brussels is the one most at risk of saturation, already from this year onwards. The analysis also showed that the situation in Liège would be difficult in certain parts of the city, but to a lesser extent than in Brussels. By contrast, only a few areas of Antwerp will be subject to a (medium) risk of saturation. This difference is mainly due to the three Regions' different emission standards: in Flanders, these are applicable separately by operator, technology and frequency band. By contrast, in Brussels these limits are applied cumulatively for all technologies and frequency bands used by each operator (and a limit of 33% of the total cumulative limit by operator) while in Wallonia they are applicable by operator and technology.

For similar reasons, the deployment of 5G networks will face very different saturation risks in each of the three regions. Because of the Flemish Region's non-cumulative emission limits, those applicable to 5G will not be affected by the level of parallel emissions from 4G and other technologies, but will be measured independently. The position should be similar in Wallonia, as its emission limits are applied separately for each technology. Brussels, on the contrary, is likely to be unable to sustain a 5G network rollout under the current EMF emission regime, as its 4G network is already close to saturation. Any new emissions from a 5G network would have to be "squeezed" into the limited remaining margin (if any) below the cumulative limit. The progressive future deactivation of 2G and 3G antennas is unlikely to be sufficient to free enough allowed emission capacity for an operational 5G network within the existing emission limits.

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22 Available on https://www.bipt.be/consumers/publication/a-study-of-the-bipt-predicts-the-risks-of-congestion-of-4g-networks.

Conclusions

Belgium is not legally bound by any EU or other international rules in its definition of the allowed emission standards for EMF. Those in place today differ by Region and are generally stricter than those recommended by the ICNIRP and the EC.

Of the three Regions, the strictest limits by far are those adopted by the Brussels-Capital Region – 50 times stricter than those recommended by the ICNIRP/EC. Moreover, and contrary to the position in the other two Regions, these standards apply cumulatively, for all technologies and frequency bands used by each mobile operator. As a result, 4G networks in Brussels are already close to saturation in several parts of the city. A rollout of 5G under this EMF emissions regime seems unachievable in Brussels, contrary to the two other Regions.

3.2. Literature review – Market structure

This subsection discusses the literature available with regards to the impact of the market structure (i.e., the number of mobile network operators) on the overall performance of the mobile telecommunications market. In particular, this subsection looks into the relevant economic and sector literature (subsection 3.2.1) and decisional practice in the EU (subsection 3.2.2).

This analysis updates and completes the one carried by the BIPT in Section 4 of its study of 26 June 2018 concerning a fourth mobile network operator on the Belgian mobile market. Similar to that BIPT study, the discussion focuses on three impact areas:

- Impact of a 4th operator on price;
- Impact of a 4th operator on quality of service and investments; and
- Long term sustainability of a 4th operator.

In all cases, and for prices in particular, the impact can be empirically assessed based on the experience gained through the entry of a 4th market player or, conversely, through the ex-post effects of 4-to-3 mergers.

By way of a background, the table below shows the number of MNOs in the EU+UK, in 2009 and today.

Country	Population (MM)	MNOs (2009)	MNOs (2021)
Austria	8.8	4	3
Belgium	11.5	3	3
Bulgaria	7.1	3	4
Croatia	4.1	3	3
Cyprus	0.8	2	3
Czech Republic	10.6	4	3
Denmark	5.8	5	4
Estonia	1.3	4	3
Finland	5.5	4	3
France	67.2	3	4
Germany	83.2	4	3
Greece	10.8	3	3
Hungary	9.8	3	4
Ireland	5.0	6	3
Italy	60.4	4	4
Latvia	1.9	3	3
Lithuania	2.8	3	3
Luxembourg	0.6	3	3
Malta	0.4	3	3
Netherlands	17.3	3	3
Poland	38.4	5	4
Portugal	10.3	3	3
Romania	19.6	6	4
Slovakia	5.5	3	4
Slovenia	2.1	4	4
Spain	46.5	4	4
Sweden	10.4	4	4
United Kingdom	68.2	5	4
TOTAL:	**515.9**	**104**	**95**
Correlation (R^2):	**0.135**		

Table 3-5: Distribution by number of MNOs and population of the EU countries [Source: Axon and EC's reports]

# of MNOs	# of countries (2009)	# of countries (2021)
3 MNOs	13	16
4 MNOs	9	12
5 MNOs	3	-
6 MNOs	2	-

Table 3-6: Distribution of MNOs by country [Source: Axon and EC's reports]

At a general level, the above table suggests that EU mobile markets are, today, somewhat more concentrated than in 2009, with a majority of Member States having three MNOs and none of them with five or more MNOs. There is very limited correlation between size of population and number of MNOs. Consolidation is not a one-way process, however: there have been moves from both 4-to-3 and vice versa in the period under consideration.

3.2.1. **Relevant literature**

Impact of a 4th operator on price

On a more global and general level, an **OECD report**[23] has confirmed the intuitive assumption that "*a larger number of MNOs is often the source for innovative offers that challenge existing market wisdom and practices and a driver for the entire market to become more competitive.*" The report also argued that this does not mean that there is no innovation in markets with three operators, as one operator can still play the role of a challenger. According to the report "*[i]t is after all the intensity of competition that is the key and there is no 'golden number' that ensures effective competition. Nonetheless, experience has demonstrated that this is more likely in a market with at least four MNOs.*"

On the question of prices in particular, the OECD report found that the entry of new MNOs has led to consumer savings both through a straightforward reduction of prices and through unlimited offers. According to the report, both effects could be seen in Austria and France with four MNOs, with the index of telecom prices in France dropping by 11 points from 2011 to 2012, and 21.5 points from January 2011 to October 2013 in Austria but then going up by 8.5 points at the end of 2013.

France in particular seems to offer a model example of a positive (from a consumer viewpoint) effect on prices through the entry of a 4th MNO. An **analysis of the impact of Free Mobile's entry in France** in early 2012[24] mentioned that the initial set of price data for mobile services dropped by 11.4% in 2012. According to the same analysis, as the weight of mobile services in the French consumer price index peaked at 1.58% in 2010 before declining to 1.1% in 2016, the decline in prices was stronger than the increase in use that had occurred. Further, and according to the price model relied on by the analysis, the entry of Free Mobile and low-cost brands launched by other operators could explain 23.4% of the mobile price decline between May 2011 and December 2014, while 56.1%

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23 OECD (2014).

24 Berne/Vialle/Whalley (2019).

of the price decline could be attributed to the introduction of 4G. Further, the impact of competition appeared to be lower on "classic" tariffs than on low-cost tariffs.

These conclusions are contested in other reports, although one should also keep in mind that these were operator-originated and therefore likely carry less weight as an independent and objective source of reference. (More generally, the same applies to other reports quoted here, for completeness' sake, insofar as these were generated by other industry players, with obvious economic stakes in the conclusions drawn.) Specifically, **a report, commissioned by Orange**,[25] concluded that the entry of the fourth MNO in France actually had a price-increasing effect, while the 4-to-3 merger in Austria had a price-decreasing effect. Using a "hedonic price model"[26] and a "double-difference matching identification strategy", the study concluded that the entry in the French market had raised the unit price of mobile data services by 4 dollars per Gigabyte. By contrast, the Austrian merger had lowered the unit price of mobile data by 6 dollars per Gigabyte. According to the author of this report, these results suggested that the dynamic efficiency effects actually outweighed the static ones in the mobile telecommunications industry.

In the same vein, **a report by Frontier Economics**,[27] commissioned by the GSMA, has argued that the use of an analytical framework known as the Gross Upwards Pricing Pressure Index (GUPPI) by competition authorities in Europe and the USA has tended to overstate post-merger price increases, while empirical evidence, *e.g.*, in Austria, suggest that unit prices post-merger were not higher than what they would have been without the merger. Similarly, according to the study, the role of mavericks has tended to be exaggerated, particularly as many of them entered the market at the time of the 3G auctions, with significantly more optimistic expectations of future profits. A diagram in the study purported to show that there was no obvious relationship between average prices, as measured using ARPM, and the level of concentration (measured using HHI) in EU countries over the last 15 years.

One way or another, Free Mobile is an example of a disruptive firm in the mobile communications landscape, e.g., through its aggressive price strategy. The effect of such disruptive MNO entrants has been the subject of a **research document by OFCOM** in 2016.[28] The document suggests ("with a 95% confidence interval") that, in countries where a disruptive player is present, prices are lower of the order of between 10.7% and 12.4%

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25 Houngbonon (2015).

26 A hedonic price model is based on the intuition that any product can be viewed as a bundle of attributes such that firms and consumers trade to determine the price attached to each attribute.

27 Frontier Economics (2015).

28 OFCOM (2016).

compared to countries where a disruptive firm was not present. Further, prices are lower of the order of between 7.3% and 9.2% in countries where there is a greater number of players. Combining these two variables suggests that prices could be between 17.2% and 20.5% lower on average in countries where there were four or more mobile operators AND a disruptive firm in the market.

The robustness of the analysis of price evolution in a 3-to-4 MNOs scenario must also be reviewed against the reverse impact of 4-to-3 mobile mergers. In a relevant **2018 report,**[29] **BEREC** has reviewed and summarized a number of studies conducted on the price effects of mobile mergers in Austria, Ireland and Germany. The table below provides a summary of the conclusions reached in the main studies referred to by BEREC on the mobile mergers' impact on price.

Title of Study	Main Conclusion	Details
Genakos, Ch. Valletti, T. and Verboven, F. *Evaluating market consolidation in mobile communications*, 2015, Centre on Regulation in Europe, available here	On average, 4-to-3 mergers result in price increases	A hypothetical average four-to-three symmetric merger in our data would have increased the bill of end users by 16.3%, while at the same time capital expenditure would have gone up by 19.3% at the operator level, always in comparison with what would happen in the case of no merger. More realistic asymmetric four-to-three mergers (between smaller firms in European countries) are predicted to have increased the bill by about 4–7%, while increasing capital expenditure per operator by between 7.5% and 14%.
Csorba, G. and Pápai, Z.: Does one more or one less mobile operator affect prices? A comprehensive ex-post evaluation of entries and mergers in European mobile telecommunication markets, August 2015, available here	No price-increasing effects of 5-to-4 mergers but long-run price-increasing effects in the only 4-to-3 sample examined	Investigated entries and mergers in the EU from 2003 to 2010
Aguzzoni, L., Buehler, B., Di Martile, L., Ecker, G., Kemp, R., Schwarz, A. and Stil, R., *Ex-post analysis of two mobile telecom mergers: T-Mobile/tele.ring in Austria and TMobile/Orange in the Netherlands*, December 2015, available here	Price increases possibly linked to a 4-to-3 merger	For the Netherlands, the authors assessed the 4-to-3 merger of T-Mobile and Orange, which was preceded by a 5-to-4 merger between KPN and Telfort in 2005, and found price increases due to the merger between T-Mobile and Orange of 10% to 15% relative to the control countries. However, the effect could be also a combined effect of both mergers (5-to-4 and 4-to-3).

[29] BEREC (2018).

Title of Study	Main Conclusion	Details
		In the case of Austria, the investigated 5-to-4 merger between T-Mobile and tele.ring did not lead to evidence of higher prices.
RTR: *Ex-post analysis of the merger between H3G Austria and Orange Austria*, March 2016, available here	The merger had a significant and strong price increasing effect for smartphone users as well as for traditional users before the merger remedies (MVNO entries) became effective.	Analysed the price developments of mobile telephony (voice and data) services in Austria in the period from 2011 to 2014 compared to international price trends.
BWB, The Austrian Market for Mobile Telecommunication Services to Private Customers. An Ex-post Evaluation of the Mergers H3G/Orange and TA/Yesss!, Sectoral Inquiry, BWB/AW-393, Final Report Vienna, March 2016, Authors: Erharter, D., Gruber, J., available here	4-to-3 consolidation led to price increases in the 10-20% range, and larger for pre-paid tariffs.	Due to the mergers, inflation-adjusted prices increased by 14–20% for the average subscriber. Price increases were largest for pre-paid tariffs (20–30%) and less pronounced for post-paid tariffs (13–17%). Within the postpaid segment, price increases were most dramatic for sim-only tariffs. However, this could to a considerable extend be explained with increased data usage. Nevertheless, the BWB's simulations suggest a merger-induced price increase of 10–15%. In the contract segment, where customers receive handset subsidies and usually are locked in for a period of 24 months, the BWB found a merger-induced price increase of 14–18%.
Affeldt, P. and Nitsche, R. (2014): A price concentration study on European Mobile Telecom Markets, ESMT Working Paper, November 2014	No higher prices in markets with 3 MNOs (but the study did not compare like-for-like, i.e., the passage from 4-to-3 or 3-to-4 in the same country).	Research conducted for Telefónica. No higher prices in markets with three MNOs compared to markets with four MNOs. There were even indications of lower prices in markets with three MNOs

Table 3-7: Summary of reports examined by BEREC [Source: BEREC]

Impact of a 4th operator on quality of service and investments

Relevant literature generally confirms the assumption that quality of mobile service and level of investment in mobile networks are closely related. However, it is less clear whether the number of MNOs in a market has any significant effect on long-term investment.

WIK, in a 2015 study for OFCOM,[30] ranked 12 countries based on the best outcome for users in terms of price, quality, and the extent of usage of services. The study explored

30 WIK (2015).

the hypothesis of a "virtuous circle" between competition and investment, or whether, more intense competition may undermine investment, harming consumer outcomes in the long term. It found no linkage between consolidation or higher concentration in mobile markets and an increase in investment. Similarly, the evidence examined by the study also did not confirm that consolidation and higher concentration in mobile markets was linked to an improvement in consumer outcomes.

In examining the impact of market concentration on investment in mobile networks, the previously cited **2016 study by Houngbonon and Jeanjean** recommended that "*policymakers should consider wireless operators' profit margin levels before allowing a new entrant or a merger in the wireless industry. When the profit margin is below 35 per cent, a merger may be a better way to raise social surplus than a new entry. On the other hand, when it is above 42 per cent an additional entrant may increase social surplus more than a merger due to higher incentives to invest. Between these two thresholds, a case-by-case analysis of merger proposals is recommended*."

The analysis performed by **Frontier Economics[31] in 2015 for the GSMA** questions the competition authorities' inclination to assume that more intense competition is conducive to stronger incentives to invest. Frontier Economics' analysis suggests that the relationship is more complex than that and that there is no strong direct link between average investment and competition in EU countries as measured by the HHI over the last 15 years.

A **2017 GSMA study**[32] examined the impact of the 2012 merger between two mobile operators in Austria (Hutchison 3G Austria and Orange) on 4G network coverage, download speeds and upload speeds. The study concluded that Hutchison was able to accelerate population coverage of its 4G network by 20–30%, within two years, as a result of the merger. Hutchison's 4G network quality also increased significantly, with 4G download and upload speeds increasing by 7 Mbps and 3 Mbps respectively two years after the merger. The GSMA study also found positive effects on the quality of mobile networks in the Austrian market as a whole, with 4G download and upload speeds increasing by more than 13 Mbps and 4 Mbps in 2013 and 2014 respectively after the merger, and 3G download speeds increasing by 1.5 Mbps after 2014.

A **2019 study by Wellman**,[33] considered 500 million measurements of the mobile network quality of 48 mobile network operators (MNO) from 14 European countries between 2011 and 2016. The study's results indicated that a reduction in market players

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[31] Cited above, in fn. 27.

[32] GSMA (2017).

[33] Wellmann (2019).

may actually increase mobile network quality. The study also observed a significantly higher mobile network quality for late entrants in the market. In the author's view, this underlined how outcomes from spectrum auctions may alter competition in the mobile market.

Wellman's study found that more competition may yield lower price levels but that this is traded-off with lower investments in the mobile network infrastructure. However, the magnitude of this effect was found to be lower than that in other studies,[34] which were more confident about the positive effects of market concentration on mobile network investments. Further, Wellman concedes that "*more work is required to get a better understanding of the underlying mechanisms and what market conditions are required such that a reduction of MNOs may actually improve mobile network quality. In any case, a simple reduction of MNOs will not be a panacea to improve mobile network quality. Instead, it needs to be embedded into a careful analysis of competition in the market and existing regulations while merging parties may need to carefully outline why their merger may actually lead to an improvement of mobile network quality*."

Similarly, a **2020 study by Abate/Bahia/Castells[35]** has looked at data covering the period Q2 2011 to Q4 2018, i.e., the majority of the "4G era" in Europe, in 29 European countries – 27 out of the 28 members of the EU, with Norway and Switzerland. Download speeds increased from below 5 Mbps in 2011 to more than 30 Mbps on average by the end of 2018. Their data showed that three-player markets were outperforming four-player markets by almost 5 Mbps (or 13% higher). The difference between three-player and four-player markets was also apparent for upload speeds, which were 16% higher in three-player markets than in four-player markets in 2018. Further, the data showed that, from 2015, MNOs in three-player markets invested more per connection and as a proportion of revenues. This was also associated with higher profitability in three-player markets. By contrast, the results for coverage did not seem to be materially affected by the distinction between three-player and four-player markets.

Long term sustainability of a 4th operator

It could be contended that the examples of consolidation from 4 to 3 mobile operators provide compelling evidence that a 4th operator may not be sustainable in certain markets. This is not necessarily true, however: market consolidation may be simply part of a normal business process in the private sector economy, and not proof that the target would be bound to fail if left to compete on its own. On the contrary, such acquisitions can simply

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[34] Genakos/Valletti/Verboven (2016).

[35] Abate/Bahia/Castells (2020).

indicate that the target represents a profitable and attractive investment, with an independently sustainable business. As will be shown from some of the EC cases discussed under the next heading, there is simply no fast rule on the extent to which market consolidation in the mobile sector can be justified through the unsustainability of the MNO to be acquired.

Another relevant factor in mobile network consolidation pre-5G may be the concept of a minimum efficient scale for a mobile network operator, which has been relied upon by regulators in the context of mobile termination rates. In a Working Document of 2009,[36] the EC referred to:

- the conclusion of the UK's Competition Commission, in 2003, that once an MNO had captured 20-25% of the market volume, there were only very limited remaining economies of scale;
- a 2007 WIK report for the Australian Competition and Consumer Commission estimating different scenarios for the efficient scale – 25% and 31% respectively; and
- an ERG assessment of 2007 that in a mature mobile market it can be expected to take 3 to 4 years for a new entrant to reach a market share of 15-20%.
- It is questionable, however, whether such earlier estimates remain pertinent in the context of 5G, a technology whose rollout in Belgium will be predicated on different assumptions than those prevalent in other markets 10-15 years ago, as discussed elsewhere in this study.

In a **2015 article,[37] Curwen and Whalley** conclude that the consequences of new entry for the state of competition in the European mobile sector have been modest at best. According to the authors, over a period of roughly 15 years, the award of 3G licences in a broad range of European countries has achieved very little by way of increased competition. The only new entrant company with any broadly based success was Hutchison Whampoa, yet until very recently it had only managed to establish itself as the smallest operator in its markets and the losses it incurred in so doing would be unsustainable for virtually any other potential entrant. Iliad and P4 had grown rapidly at the expense of the incumbents but had yet to attain more than a 15% market share. That most of the new

[36] Commission Staff Working Document accompanying the Commission Recommendation on the Regulatory Treatment of Fixed and Mobile Termination Rates in the EU, Explanatory Note, SEC(2009)600.

[37] Curwen/Whalley (2015).

entrants had yet to gain more than that market share vividly illustrated the scale of the challenges and difficulties that they were facing competing against their larger and well-established rivals.

The authors further remarked that new entrants have sought to succeed through adopting a disruptive strategy. However, while such a strategy of undercutting incumbent prices and offering better data allowances may have contributed to their growth, it was hardly the optimum route to achieving a decent return on capital. The final conclusion was that, without either the necessary scale or return on capital, the (smaller) new entrants are unlikely to remain in the market.

In discussing the case of Free Mobile in France, **Berne, Vialle and Whalley**[38] have argued that a converged operator seems more likely to have a strong impact on competition and to be more sustainable than a pure mobile operator. Further, a will to be disruptive, (as exemplified by the personality of Xavier Niel in the case of Free Mobile), can also play a role. They also point to new entries' potential downsides for overall industry sustainability, however, as in their view industrial and competition policy objectives are difficult to reconcile. According to the study, the concerns expressed before the entry of Free Mobile by incumbents had proven to be true, to some extent: not only had employment and profitability in the industry been severely affected, but the incumbents had been globally weakened with two of them experiencing difficulties in maintaining the sustainability of their operations.

3.2.2. The European Commission's position

Decisional practice in the EU in mobile consolidation transactions has been almost entirely left to the European Commission, despite various requests by national competition authorities that such cases be referred to them.

The relevant position of the EU and, in particular, the European Commission (EC) has been articulated more authoritatively in a number of 4-to-3 and other mobile consolidation cases it has dealt with under the EC Merger Regulation. By contrast, the EC has no power to request Member States to move from 3 to 4 MNOs. At most, it has mentioned such a prospect in the past as a means to encourage competition in certain mobile markets.

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[38] Cited above, in fn. 24.

The Commission has approved several 4-to-3 and 5-to-4 mobile consolidation transactions in the EU, with one exception (H3G/Telefonica, even if this was the appealed successfully by the parties). The table below provides an overview of these EC cases.

Parties	Country & year	Type of deal	Combined market share	Outcome
T-Mobile & tele.ring	Austria (2006)	5 to 4	30-40%	Approved in Phase II, with conditions
T-Mobile & Orange	Netherlands (2007)	4 to 3	40-50%	Approved in Phase I
T-Mobile & Orange	UK (2010)	5 to 4	30-40%	Approved in Phase I, with conditions
H3G & Orange	Austria (2013)	4 to 3	less than 25%	Approved in Phase II, with conditions
H3G & Telefonica	Ireland (2014)	4 to 3	about 40%	Approved in Phase II, with conditions
Telefonica & E-Plus	Germany (2014)	4 to 3	30-40%	Approved in Phase II, with conditions
Telia Sonera & Telenor	Denmark (2015)	4 to 3	more than 40%	Abandoned, in light of the Commission's competitive concerns
H3G & Telefonica	UK (2016)	4 to 3	more than 40%	Prohibition – but appealed successfully
H3G & Wind JV	Italy (2016)	4 to 3	30-40%	Approved in Phase II, with conditions
Tele2 & T-Mobile	Netherlands (2018)	4 to 3	20-30%	Approved in Phase II

Figure 3-10: Summary of past MNO merger decisions [Source: Axon]

As can be concluded from this table, EC approval is almost always subject to conditions, and may require massive information and negotiation of complex remedies in Phase II, as also recounted in detail in approval decisions of hundreds of pages.

A review of the EC decisions shows that these turn on specific facts and markets, and do not lend themselves to simple lessons.

For example, a "failing firm defence"[39] has been used unsuccessfully in at least one case, but successfully in another. In ***H3G/Wind***,[40] the parties argued that, acting independently, they could not invest in 4G network rollout and remain competitive, because of Wind's high debt and H3G's lack of incentives. The Commission rejected these arguments and stated that, for each party, the appropriate counterfactual should consider:

[39] i.e., the argument that the proposed acquisition will not lead to a substantial lessening of effective competition, as the target has been unprofitable and is bound to exit the market in any case.

[40] Case M.7758 *Hutchison 3G Italy/Wind/JV*, European Commission Decision of 1 September 2016.

- the pre-merger operational and financial performance;
- best estimates of the future performance of each party's telecommunication business in the absence of the Transaction, as captured in its pre-merger forward-looking projections; and
- possible alternative steps that could reasonably have been taken by H3G to maintain or strengthen the competitiveness of its business, other than the planned JV.

By contrast, the European Commission has accepted a "failing firm" defence in its clearance of the **T-Mobile/Tele2** 4-to-3 merger, two years later.[41] Two scenarios were examined in the decision: Tele2 NL would either continue on the same basis or it would eventually exit the market. Even under the first, and more optimistic, scenario, its network would require significant investment to remain competitive, which would lead to increased incremental costs and less-competitive pricing.

It has been argued that the annulment, by the EU General Court, of the Commission's prohibition of H3G/Telefonica may facilitate the approval of similar mergers in the future. This remains to be seen, also pending the outcome of the European Commission's appeal before the European Court of Justice.

3.2.3. **Conclusions**

- Studies conducted by regulators generally suggest that the entry of a fourth MNO, with a disruptive business model, can be **reasonably expected to lead to reduced mobile retail tariffs, at least in the short run** (e.g., the first 1-2 years), in the range of 10-15% and possibly higher. These conclusions are contested by some economists, typically commissioned by MNOs, who rely, at least in part, on dynamic efficiencies and more sophisticated theoretical analysis tools.
- In this context, the ability of the fourth MNO to have a **disruptive effect on the market is crucial**. It can be assumed that this ability will be more limited in saturated and technologically mature markets, and higher in technology markets at an early stage of development, favouring new commercial models.
- The conclusions reached in literature on the impact of three vs. four MNOs on the above studies on **quality of service and investments** are not unambiguous and remain subject to caveats. There is, in particular, no clear evidence that the presence

[41] Case M.8792 *T-Mobile NL/Tele2 NL*, European Commission Decision of 27 November 2018.

of four instead of three MNOs in a market will contribute more positively to overall market investment. However, factors other than the number of MNO operators active in a market may have a more significant impact on investment and hence also quality of service. Such factors include, in particular, the operators' operating margins, and the industry's general projections on future profits from the mobile network technology it is asked to invest in. While these factors too may be linked to the number of competing MNO operators, they are ultimately a function of a broader set of market-specific parameters.

- The literature examined offers limited guidance on the **sustainability of a 4th MNO offering (at least) 5G**. Earlier studies have suggested that MNOs need at least a 20-25% market share for a minimum efficient scale, and that the 4th market entrants have been unable to exceed a 15% market share threshold and would not have survived without financial backing from a powerful group. It is worth asking, however, whether such conclusions, drawn in a 3G/4G environment several years ago will also hold true in a market enriched, and ultimately driven, by 5G and the new business models it is expected to offer.

- Case-law of the EC suggests that it implicitly recognizes that a 4 MNO market is substantially more competitive than a 3 MNO market. This is why the EC has generally insisted on remedies and/or an in-depth Phase II review in all 4-to-3 transactions it has reviewed, one of which was ultimately abandoned (in light of the competitive concerns expressed) and one prohibited.

The table that follows provides a simplified overview of the main takeaways from the literature and other references discussed in this subsection (+ = positive effect; - = negative effect; (+) = possible positive effect; (-) = possible negative effect; ± = neutral, mixed or undetected effect). As mentioned already, industry reports and industry generated studies by external experts do not necessarily carry the same objective weight as those carried by parties with less obvious stakes in the outcome of the analysis. Nevertheless, as a distinction between the two types of sources risks being contestable and subjective, we have included in the list all of the sources examined, for quick reference purposes.

IMPACT OF ENTRY OR PRESENCE OF A 4TH MOBILE NETWORK OPERATOR			
Author or reference	**Price[42]**	**Quality & Investments**	**Long-term sustainability of 4th MNO**
Abate/Bahia/Castells (2020)		-	
Affeldt/Nitsche (2014)	±		
Aguzzoni & others (2015)	(+)		
Aimene/Jeanjean/Liang (2021)	±		
Berne/Vialle/Whalley (2019)	+		±
BWB (2016)	+		
Csorba/Papai (2015)	+		
Curwen/Whalley (2015)			(-)
Frontier Economics (2015)	±	±	
Genakos/Valletti/Verboven (2015)	+		
GSMA (2017)		+	
Houngbonon (2015)	-		
Houngbonon/Jeanjean (2016)		±	
OECD (2014)			
OFCOM (2016)	+		
RTR (2016)	+		
Wellman (2019)		(-)	
WIK (2015)		±	

Figure 3-11 : Summary of the impact of a 4th MNO [Source: Axon]

3.3. Literature review – 5G

While it is unusual for a new technology to elicit as many hopeful expectations as 5G, these are also countered by sceptics invoking economic, environmental, health or other concerns. In this section, we provide a description of the main such benefits and risks identified in the relevant recent literature and studies reviewed for the purposes of this study.

[42] A positive sign for price (+) means that prices are expected to fall through the entry of a 4th operator.

3.3.1. **Benefits expected from 5G**

An enabling technology

The main general benefit expected from 5G is its role as an accelerator and enabling technology for a vast range of other, independently developed, technologies. These will, in turn, support and significantly improve existing services and applications, or create new ones. As summarized by the EC, 5G should "*provide virtually ubiquitous, ultra-high bandwidth, and low latency 'connectivity' not only to individual users but also to connected objects. Therefore, it is expected that the future 5G infrastructure will serve a wide range of applications and sectors including professional uses (e.g., Connected Automated Mobility, eHealth, energy management, possibly safety applications, etc)*."[43]

Among other technical improvements, 5G:[44]

- can theoretically offer speeds of up to 100 times faster than 4G;
- offers ultra-reliable low latency communication should reduce latency by a factor of 10, down to single-digit milliseconds (as compared to 50 milliseconds for 4G);
- allows the partitioning of the same physical network into multiple virtual networks, each optimized for different applications, ("network slicing"), hence lowering costs and time to market;
- is energy-efficient, with power consumption reduced up to 90%.

Therefore, 5G has the potential to enhance the impact of other, independently developed, technologies and services. The resulting expected benefits are described in the examples below:

- Its high reliability and ultra-reliable low latency allow 5G to support ultra-high-definition video (e.g., for high-definition real-time gaming) and other bandwidth hungry applications, as well as mission critical services, such as autonomous vehicles, drones and other autonomous robotic applications, remote operation of automated equipment, smart grid and metering; intelligent transportation, etc.
- 5G can help solve or improve connectivity in the manufacturing industry, transport hubs, logistics, energy and utilities, and thus contribute to **significant industrial**

[43] https://digital-strategy.ec.europa.eu/en/policies/5g.

[44] Capgemini (2019).

advances. In a recent study,[45] Capgemini have surveyed around 800 manufacturing and asset-intensive companies across the world and 150 telecoms executives. They conclude that, for the industry at large, key use cases drawing on 5G include:

- Real-time analytics leveraging edge computing
- Video surveillance of remote production lines
- Remote control of distribution production line
- AI enabled and remote-controlled motion, such as collaborative robots, self-driven cars and drones
- Real-time service and breakdown alerts
- Remote operations/maintenance/training solutions through AR/VR; and
- Predictive/preventive maintenance.

- In the same vein, the World Economic Forum predicts that 5G will contribute to industrial advances by (i) enabling faster and effective inspections through predictive intelligence; (ii) improving workplace and worker safety; and (iii) enhancing operational effectiveness. 5G also has the potential to impact industry by managing the carbon footprint and bridging the digital divide.[46]

- 5G can support Artificial Intelligence and Machine Learning systems, providing real-time data collection and analysis[47] also including Big Data;

- As 5G can support up to millions of devices per km2, it is a key enabler for a substantial expansion of IoT use cases, offering both speed and the capacity to handle distributed intelligence, at the device level.[48] According to an earlier study,[49] building on earlier investment in M2M and IoT, 5G can help address "Massive internet of Things" (MIoT) applications in areas such as asset tracking, smart agriculture, smart cities,[50] energy/utility monitoring, physical infrastructure, smart homes, remote monitoring, beacons[51] and connected shoppers.

- 5G can boost cloud services by enabling fast and flowless distribution of computing and storage throughout the infrastructure (edge cloud, mobile edge computing),

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45 Capgemini (2019).

46 World Economic Forum (2020).

47 https://digital-strategy.ec.europa.eu/en/policies/5g.

48 Capgemini (2019).

49 IHS Economics & HIS Technology (2017).

50 For the example of the 5G's impact on smart cities and intelligent transportation, see Guevara/Cheein (2020).

51 i.e., small wireless sensors that send low energy signals to nearby mobile devices.

especially as its more flexible network architecture supports more distributed intelligence, at the network edge.[52] In fact, in a Capgemini survey,[53] cloud computing topped the industries considering 5G a key enabler of their digital transformation.

Benefits expected to outweigh costs

While the costs of 5G network rollout are expected to be considerable, industry analysts argue that benefits will largely outweigh these costs. In a very recent study,[54] Analysys Mason estimate that the open innovation platform of full 5G networks in Europe will be able to deliver € 208 billion of benefits, at a cost of approximately € 36 billion, between 2025 and 2040. The benefits will be distributed between smart production (€ 68 billion), smart rural (€ 54 billion), smart urban (€ 29 billion net, i.e., benefit minus cost) and smart public services (€ 10 billion).

Analysys Mason estimates that the cost of 5G enhanced mobile broadband (eMBB) roll-out in Belgium, expressed in "Present value (PV) of 5G eMBB costs (2019–2040), per mobile network" will be € 1.215 million. This estimate excludes all non-network costs, spectrum costs and the costs of operating/maintaining/upgrading legacy networks (e.g., 2G/4G), as well as any costs that may be incurred by requirements to remove Huawei equipment from a network. Aggregated present value of 5G eMBB costs (2019–2040), across all MNOs in Belgium is estimated at € 3.246 million.[55]

Further, according to Ericsson's 2019 estimates, 5G has the potential to unlock related ICT revenues of € 8 billion by 2030 in Belgium, and aggregated revenues of up to € 41 billion between 2020 and 2030, for operators and other ICT players. The € 8 billion figure is distributed as follows between "case clusters" addressing several industries (e.g., enhanced video services, real-time automation, monitoring and tracking etc) and industries addressed:

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[52] https://digital-strategy.ec.europa.eu/en/policies/5g.

[53] Capgemini (2019).

[54] Analysys Mason, Further investment in 5G infrastructure could lead to over EUR160 billion of benefits in Europe, (2021).

[55] Analysys Mason, Analysis of the costs and benefits of 5G geographical roll-out in Europe, (2021).

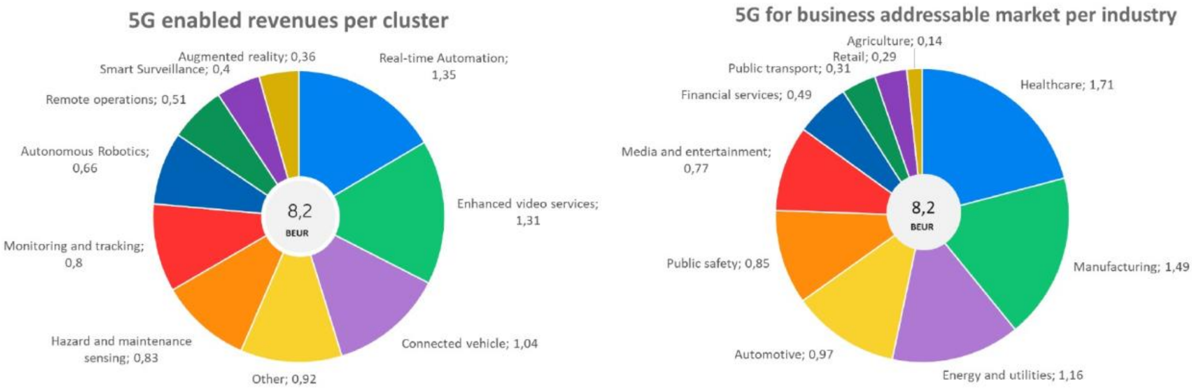

Figure 3-12: Potential ICT Revenues from 5G in Belgium [Source: Ericsson, Analysis Belgium Market, October 2019]

Positive social impact

The World Economic Forum estimates that 5G can deliver social value across 11 key UN sustainable development goals, such as contributing to good health and well-being, enhancing infrastructure, promoting sustainable industrialization, fostering innovation, contributing to responsible consumption, enabling sustainable cities and communities, and promoting decent work and economic growth.[56]

According to one study, in the USA, 5G and related technologies are expected to create 4.6 million jobs relative to the baseline in 2034, 15 years after the introduction of 5G in 2019. Generally, these are expected to be higher paying jobs that will replace jobs that are lost in a wide range of industries and use cases.[57] Examples of "white collar" jobs (referred to as "cognitive jobs") and a mix of "blue collar/white collar" jobs (referred to as "cognitive physical" skilled jobs) identified in this study are shown in the exhibit below.

[56] World Economic Forum (2020).

[57] Progressive Policy Institute (PPI) (2020).

"COGNITIVE" JOBS	"COGNITIVE PHYSICAL" SKILLED JOBS
Precision agriculture software developer	Field sensor technician
Remote construction database developer	Construction drone operator
Smart grid analyst	Household smart meter maintenance
Digital manufacturing platform developer	Robotics maintenance
Mobile logistics analyst	Autonomous vehicle maintenance
Online learning platform specialist	Elementary-high school telecom help desk
Health cloud information security specialist	Telehealth installer
Government database privacy specialist	Tactical communications specialist

Figure 3-13: Expected job creation through 5G (USA; Source: PPI)

Energy Efficiency

Energy needs for 5G deployment can be both a benefit and a challenge for the industry. On the positive side, 5G energy consumption per bit is estimated to be as much as 90% lower than 4G. 5G also offers greater "energy elasticity" and can be turned down during off-peak times. It can also offer faster, cheaper renewal cycles, continuous improvements in software/hardware, and greater opportunities for resource sharing, e.g., through network slicing. As 5G gradually replaces 2G/3G/4G networks, the decommissioning of their obsolete infrastructure should bring further environmental and energy consumption benefits.

At the same time, however, 5G is expected to lead to the deployment of a massive number of small cells, pressured by an expected 20-25% YoY increase in data consumption. It is also likely to trigger the introduction of new, energy-consuming, technology and devices (e.g., edge servers and datacentres, and intelligent devices).

On the whole, different factors are said to push power consumption downwards or upwards, thus complicating the assessment of the overall 5G impact on power consumption. Despite the underlying difficulty of this exercise, section 4.2.2 provides an assessment of the expected range of impact of 5G on power consumption in Belgium by 2030.

3.3.2. **Risks and obstacles associated with 5G**

Potential impact on human health and the environment

The most high-profile potential risk associated with 5G and discussed in relevant literature and public fora is its potential negative impact on human health and the environment from higher frequencies and a huge number of additional connections, which will presumably expose the majority, if not the whole, of the population to constant exposure. As discussed in Subsection 3.1.4, regulatory initiatives in place aim to address such concerns. Research to date has not demonstrated any related health or environmental risks, but it is yet to be considered complete.

Critics of the official position on the absence of any health risks, as expressed by ICNIRP and the EC, claim that conflicts of interest and ties to the industry seem to have contributed to biased official reports, minimizing or refuting potential health risks.[58] As an example of a contrary scientific view, a study from a communications engineering viewpoint argues that, overall, the widely perceived health risks that are attributed to 5G are not supported by scientific evidence.[59]

Overall, the ICNIRP is widely regarded as the most respectful and reliable institution in the assessment of the potential impact of non-ionising radiations on human health, and its findings have been widely shared by a broad number of international organizations, including the European Commission. Among the main traits that characterise the ICNIRP, we may highlight that:

1. It is a non-profit organization that has continuously provided recommendations on NIR limits across a wide range of frequencies since 1992, much before the recent growing concerns on radio waves' impact on human health and the deployment of 5G.
2. Its members are subject to a thorough declaration of personal interests[60] to prevent any potential conflicts.
3. Its conclusions are based on scientific methods, involving experts from different countries and disciplines such as biology, epidemiology, medicine, physics, and chemistry.

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[58] See, e.g., Hardell/Cardber (2020), with further references.

[59] Chiaraviglio/Alouini (2020).

[60] See here

A very recent and exhaustive report by the French Agency for Food, Environmental and Occupational Health & Safety (ANSES)[61] mainly re-confirmed the findings of the ICNIRP, concluding "*5G: no new health risks based on available data*".

Section 4.2 provides further insights into the expected impact of 5G on environment.

Political and regulatory hurdles

Political and regulatory hurdles have not been properly addressed yet in several jurisdictions. The rollout of 5G networks is lagging behind the industry's expectations, a section of which is keen to implement 5G solutions as soon as possible.[62] Both industrial users and telcos need a clearly defined implementation roadmap. As regards Belgium in particular, feedback from survey conducted for a Capgemini Invent and Agoria study[63] suggests that, according to the surveyed parties' perception, Belgian politics are the root cause for these delays and concerns, as shown in the Exhibit below.

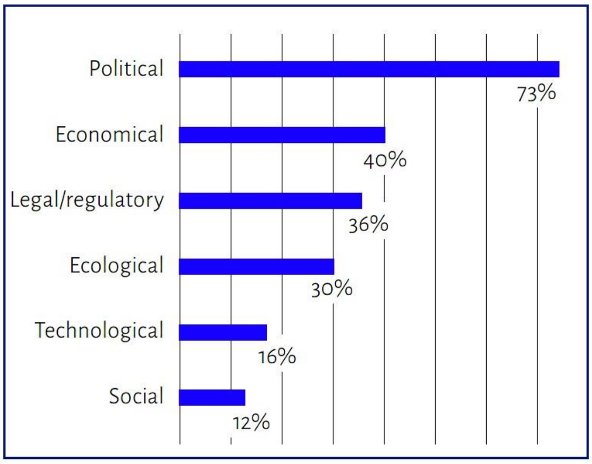

Figure 3-14: Perceived blocking factors for 5G [Source: Capgemini Invent/Agoria]

Regulatory restrictions on private 5G networks

Private 5G networks are generally described as an opportunity for a range of large businesses, such as manufacturing plants, logistic centres or ports, to build and maintain their own 5G network, using their own or leased spectrum. Such a solution can offer the advantage of enhanced security, adjustments to a location's or end-user's specific needs,

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[61] See here

[62] Capgemini/Agoria (2019). The percentage of such interested companies was 30% of the industrial companies surveyed in Belgium.

[63] Agoria/Capgemini Invent, *Time to connect Belgium with 5G*, 2019, available here.

more finely tuned quality, faster response through local maintenance and repair, etc.[64] Such arrangements can also create a margin for partnerships with other parties.

However, it is a plain fact the regulatory environment in many countries is not ready to accommodate such industry interest for private 5G networks especially when it comes to the assignment of a valuable scarce resource, such as 5G spectrum and any associated licence obligations. As regards Belgium, and while a couple of B2B test or pilot projects involving private 5G networks have been already initiated relying on a test licence, more clarity on the definitive licensing regime will need to await the adoption of the regulations on the rights of use of 5G frequency bands.

Social Impact

Notwithstanding 5G's positive social impact mentioned above, the timing and price of 5G adoption may create **first-comer advantages that will widen economic gaps between countries and social groups**.[65] In this context, a Capgemini Invent and Agoria study in Belgium has found that the level of awareness fluctuates considerably depending on size, age and location of the companies interviewed. While all large companies have heard about 5G, SMEs with a workforce between 50 and 100 employees and aging between 1 and 3 years, have a level of awareness on 5G below 60%. Similarly, the level of engagement increases with company size; but it also varies by region (Flanders: 15%, Brussels: 9%; Wallonia: 7%).[66]

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[64] Deloitte (2020).

[65] See, for example, Nyamapfene (2016).

[66] Agoria/Capgemini (2019).

4. Assessment of 5G implications in Belgium

This Section examines the expected economic and environmental impact of 5G in Belgium, based on existing literature, our further estimates and various alternative scenarios.

As regards the economic impact, which is discussed in Subsection 4.1, we distinguish between the impact on economy and employment in Belgian society at large, and the impact on revenues and investment in the telecommunications market. For the environmental impact (Subsection 4.2), we focus on 5G's impact on (i) electromagnetic radiation, (ii) power consumption, (iii) e-waste, (iv) GHG emissions and (v) visual, noise and air pollution impact.

4.1. Economic impact

5G is already seeing clear momentum in the global economy thanks to the enabling effect of this new technology on innovation. Whilst theoretic use cases for ultra-low latency (ULL), massive machine type communication (mMTC) and enhanced mobile broadband (eMBB) are prevalent throughout the literature on 5G and its effects, we are also already seeing a wave of VC-backed enterprises creating novel applications that are dependent on technological advantages 5G can provide.

The enabling effect that 5G technology promises therefore offers clear opportunities for the telecoms industry itself (through an increase in new potential clients and their demand for data), new digital market players, and wider society as a whole. However, the impact of 5G will not be geographically uniform, as it is bound to be more significant in the more open and digital-ready economies.

This section explores the various studies that have been prepared to date assessing the economic and societal impact of 5G and draws Belgium-specific conclusions based on the observations that may be extracted from them. In particular, this section assesses 5G:

- Impact on society
- Impact on the telecommunications market

4.1.1. **Impact on society**

Economy

While 5G technology can be superficially described as an incremental innovation, simply advancing the speed, volume and reliability of existing mobile telecommunication capabilities, the effect it is expected to have is to make possible many radical innovations that rely on such drastically improved connectivity. As such, 5G is termed a "revolutionary" technology, and has even been compared to previous technologies such as the printing press or the steam engine.[67]

In terms of the major economic value to be delivered by 5G, most of the expected benefits are attributed to use cases outside of traditional telecoms services. From an extreme perspective, 5G use cases in industries such as automotive and transport (where connected or autonomous vehicles are becoming a reality) are tipped to be some of the largest economic contributors, while industries such as health (where innovations like remote surgery or augmented/virtual reality (AR/VR) training are possible) are expected to derive the largest social benefit from 5G. As such, the economic and social benefit attributed to the telecom sector itself, *e.g.* through providing improved data services and OTT bundles, may ultimately be dwarfed by the wider economic effect of 5G.

Putting a figure on the economic contribution of 5G is a somewhat speculative exercise, but a number of reports have attempted to do just that. The table below shows some examples:

Reference	Conclusion reached	Yearly impact on the Belgian economy by 2030	Relevant considerations
Analysys Mason (2021)[68]	Cumulative impact of 1.15 bn EUR by 2030 and 4.16 bn EUR by 2040 in Belgium's GDP	~0,2 bn EUR 0,04% uplift to GDP	- Uniform distribution of 4,16 bn EUR over 20 years - 2030 Belgium GDP assumed to be 500 bn EUR
Accenture (2021)	Cumulative impact of 29 bn EUR between 2021 and 2025 in Belgium's GDP	~6 bn EUR 1,2% uplift to GDP	- Uniform distribution of 29 bn EUR over 5 years - 2030 Belgium GDP assumed to be 500 bn EUR

[67] FierceWireless (2017), "Qualcomm releases study behind claims 5g will be as revolutionary as electricity". Available at https://www.fiercewireless.com/tech/qualcomm-releases-study-behind-claims-5g-will-be-as-revolutionary-as-electricity

[68] Analysys Mason (2021). "Analysis of the costs and benefits of 5G geographical roll out in Europe: final report".

Reference	Conclusion reached	Yearly impact on the Belgian economy by 2030	Relevant considerations
PwC (2021)	1% uplift to national GDPs (globally) by 2030	~5 bn EUR 1% uplift to GDP	- 2030 Belgium GDP assumed to be 500 bn EUR
Ericsson (2019)	Cumulative impact of 41 bn EUR between 2020 and 2030 in Belgium's GDP	~4 bn EUR 0,8% uplift to GDP	- Uniform distribution of 41 bn EUR over 10 years - 2030 Belgium GDP assumed to be 500 bn EUR

Table 4-1: Expected yearly contribution of 5G to the Belgian economy, based on relevant reports published to date [Source: Axon]

With the exception of the Analysys Mason report, which has very modest expectations on 5G's annual impact on the Belgian economy, all reports reach comparable conclusions on **annual contribution to Belgium's GDP, estimated to be between 4 and 6 billion EUR by 2030, or 0.8% to 1.2% of GDP**.

According to the literature reviewed, 5G's largest economic impact rests in the ability of operators to serve other industries directly, based on the development of 5G use cases by third parties. Different levels of 5G connectivity are therefore required for different use cases, making the degree of rollout of 5G connectivity an important factor in its indirect economic impact.[69]

For Europe, literature points towards specific high-impact sectors or environments where 5G will result in some of the largest contributions to the economy (see Figure 4-1 for an example). As mentioned above, automotive is considered a high impact sector, by several studies, largely due to the transformative effect ULL connectivity can have on mobility. On the other hand, mMTC that can provide the circulation of data between mass-scale devices and platforms alike will help drive major advances in production, therefore playing a key role in the "Industry 4.0" revolution and unlocking a great deal of economic value for the industry. Likewise, combinations of high-speed machine and user communication afforded by eMBB will enable large economic gains in areas such as smart cities, smart homes and healthcare.

[69] ETNO, Connectivity & Beyond, cited above.

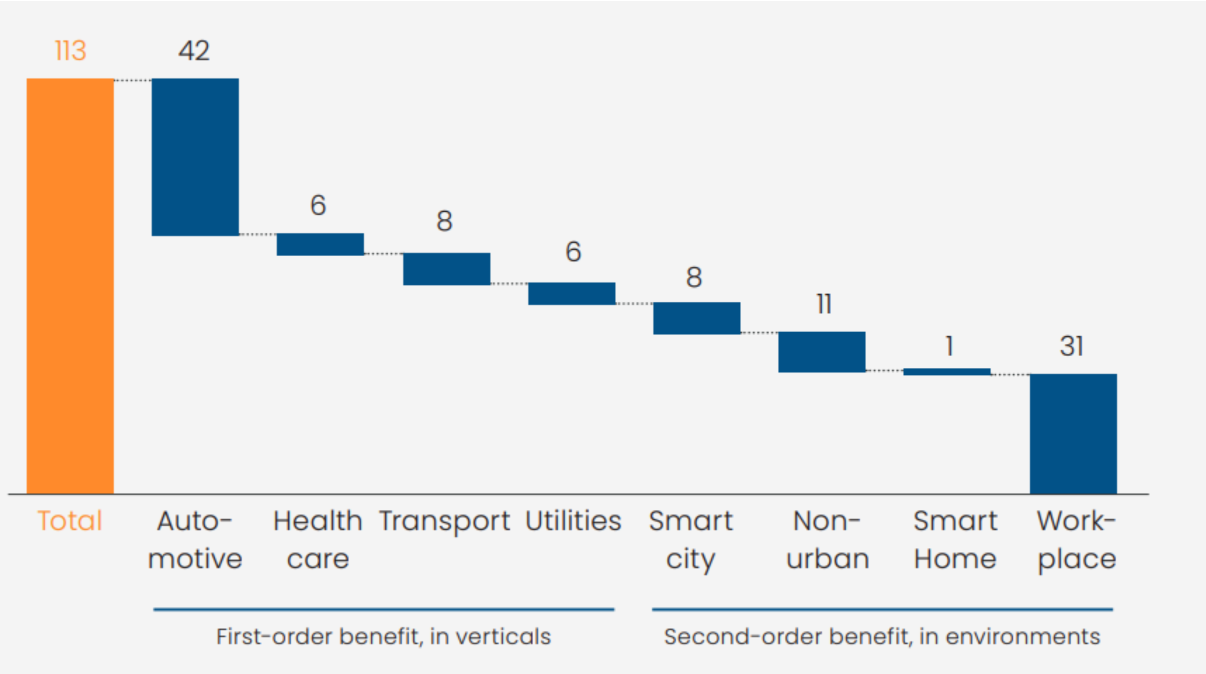

Figure 4-1 - Estimated 5G impact on European economy by vertical and environment [Source: EC]

Employment

The impact of 5G on employment is two-fold. According to the literature reviewed, the implementation and rollout of 5G by the telecoms industry will require manpower in the areas of engineering and construction. Alternatively, the use of 5G will indirectly affect employment in the wider ICT sector and in other industries, partly through the human resources required to develop and provide 5G enabled use cases, but also due to both the boosting and disruptive effects that such innovation will have on certain industries.

Therefore, once again, the effect of 5G on the wider industry is largely dependent on advances in complementary technologies such as Big Data, Internet of Things (IoT), Artificial Intelligence (AI), etc., which will create opportunity for disruptive changes in the job market. At the public policy level, the European Commission has been proactive in its policymaking to this end, having adopted a number of policies and action plans to help accelerate and remove obstacles to European development in these areas.[70,71,72] This is especially important for 5G driven employment in Europe, since technology sovereignty is highly dependent on Europe competing well on the global stage in these areas.

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[70] European Commission – AI policy - https://ec.europa.eu/digital-single-market/en/artificial-intelligence

[71] European Commission – Big Data policy - https://ec.europa.eu/digital-single-market/en/big-data

[72] European Commission – Industry 4.0 policy - https://ec.europa.eu/digital-single-market/en/policies/digitising-european-industry

The contribution of 5G to employment has been assessed in various reports, such as those shown below:

Reference	Conclusion reached	Impact on Belgium jobs number	Relevant considerations
Accenture (2021)	Generation or transformation of 560,000 jobs in Belgium between 2021 and 2025.	Unclear in terms of job creation	Considers not only creation but also transformation of jobs.
European Commission (2016) and ETNO (2021)	Generation of 36,300 jobs by 2025 in Belgium.	36,300 jobs Increase of ~1%.	
American Enterprise Institute (2020), Progressive Policy Institute (2020), Accenture (2017), BCG (2021)	All sources point to a tight range of 3-4 million jobs created in the US.	Average of +87,500 jobs Increase of ~2%.	Job estimation for Belgium based on its 1/40 ratio of US' GDP.

Figure 4-2: Impact of 5G on employment [Source: Axon]

Leaving aside Accenture's estimate, which includes both job transformation and job generation, the references available point to the generation of roughly 40.000-80.000 jobs in Belgium thanks to the introduction of 5G. Overall, it could thus be argued that 5G may contribute to an increase of 1-2% in the total workforce in Belgium by 2030.

In line with the observations made on 5G's impact on the economy, these jobs will be mostly driven by developments in verticals that make use of 5G rather than directly in the telecoms sector itself through traditional services and operations, where no relevant long-term impact on employment is foreseen. However, this does not necessarily mean that telecoms operators themselves cannot be the ones to offer some of these new services, and therefore capture a portion of this new employment, by competing directly with tech companies as B2B service providers. As such, employment in the telecoms field will be highly dependent on operators' ability to innovate and/or vertically integrate.

4.1.2. **Impact on the telecommunications market**

Revenues

For MNOs, the impact of 5G is anticipated to have a boosting effect on revenue lines due to the new opportunities to offer value to consumers. Despite the importance of B2B channels for this boost, mobile itself will also be a way to increase revenues, for example by bundling newly available OTT services, such as virtual reality.

Quantified estimations of the full impact of 5G on MNOs' revenues are given below:

Reference	Conclusion reached	Impact on Belgian operators' revenues	Relevant considerations
Ericsson (2019)	Increase of between 1 to 4 bn EUR in Belgian operators' revenues by 2030	+1-4 bn EUR +50-200% from current levels (+4-11% per year)	-
ABI Research (2016)	Increase of 247bn USD in operators' revenues worldwide	+0.7 bn EUR +30% from current levels (+3% per year)	Belgium's figures estimated considering that its mobile market's revenues represent ~0,3% of the world's mobile revenues.
Accenture (2021)	Increase of 123.4 bn EUR in the ICT sector's revenues by 2025.	+~2.5 bn EUR +110% from current levels (+8% per year)	Belgium's figures estimated considering that its mobile market's revenues represent ~2,0% of the EU's mobile revenues.
ETNO (2021)	Increase of 345 bn EUR in operators' revenues in Europe	+~7 bn EUR +~300% from current levels (+15% per year)	Belgium's figures estimated considering that its mobile market's revenues represent ~2,0% of the EU's mobile revenues.
Capgemini (2020)	- Traditional revenues flat - New use cases revenues up significantly. - Combined growth of ~3,6% a year.	+~1 bn EUR +40% from current levels (+3,6% per year)	- Projections up to 2030 have been considered. - Absolute impact estimated based on the mobile market's revenues (see section 3.1.3) instead of Capgemini's revenue figures.

Table 4-2: Impact of 5G on operator's revenue [Source: Axon]

Based on these estimates, and considering the current size of the mobile telco market in Belgium of 2.2 bn EUR (see subsection 3.1), these projections imply that the market could double in size, thanks to the deployment of 5G, by 2030 if not earlier. However, most of these reports provide a limited analysis of the cannibalisation, through these extra revenues, of existing revenues from the provision of 2G-4G services. When factored in, we believe the revenue increase to be expected from 5G should be more modest.

In this context, it is worth considering the implications of the Figure below, which shows the average evolution of mobile market revenues (in constant USD and indexed to 100 for the year 2005) across EU markets from 2005 until 2019.

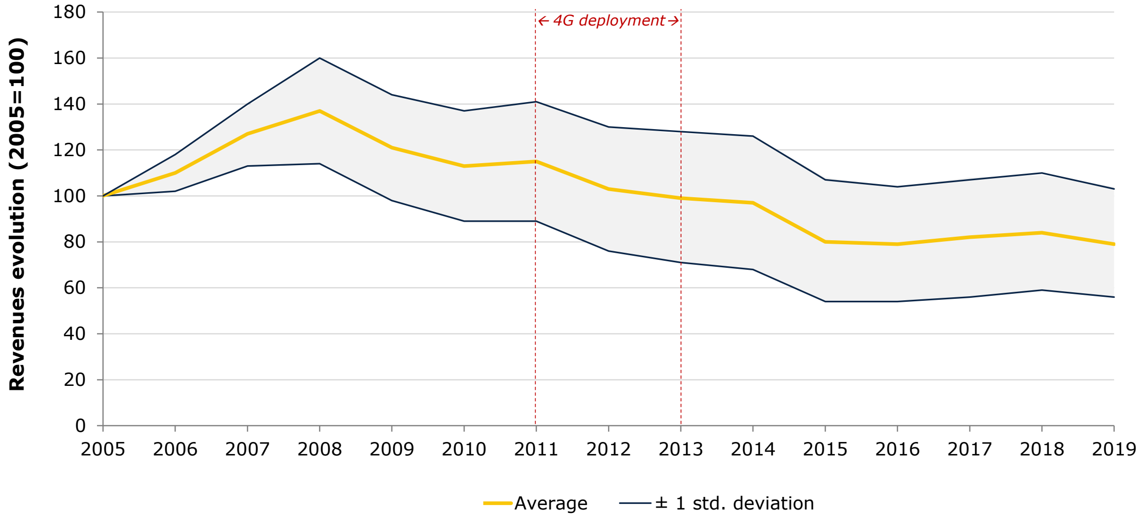

Figure 4-3: Average evolution of mobile market revenues in European markets in constant USD and indexed to 100 for the year 2005 [Source: Axon based on the ITU's WTI 2020 database]

This Figure shows that the effect of revenue cannibalisation when 4G was introduced was higher than the additional revenue generated by 4G, despite the abundance of reports at the time claiming that 4G would lead to higher market revenues.

Therefore, and despite the projections made in the reports discussed earlier, we do not think 5G will have a noticeable impact on operators' "traditional" revenues (i.e., revenues from the provision of voice and data services in the B2C market). Instead, the main opportunity for revenue generation presented to MNOs requires stepping outside of the traditional area of telecoms and focusing more heavily on the provision of products and services in the B2B market, capitalising on demand for new connectivity solutions whilst leveraging their key position as connectivity providers. There is, therefore, no definitive revenue boost that will be afforded to MNOs through 5G without operators adopting bold strategies and performing well against and within the existing tech market. **Although highly speculative, and with large differences across the board, 5G could have the potential to allow MNOs to increase their total revenues by up to 4% a year until 2030**, provided they are capable of exploiting the new possibilities that are to come in the B2B market.

5G can therefore even be said to leave MNOs in an uncertain position, with their ability to secure revenues being largely dependent on their vision and ability to capture downstream market opportunities enabled by 5G. Some reports even suggest that such revenue streams could make up as much as two thirds of telcos' top line by 2025[73], implying that those who fail to make such changes could disappear from the market.

Investment

Based on the existing literature, there is overwhelming expectation that MNOs will require significant investment in order to implement 5G, owing mostly to the large network upgrades and deployments needed. The following table lists many of the quantified estimations of investment:

Reference	Conclusion reached	Impact on Belgian levels of investment	Relevant considerations
Analysys Mason (2021)[74]	Cumulative impact of 2,4 bn EUR by 2030 in Belgium	2.4 bn EUR ~0,3 bn EUR annually	~80% of this investment is estimated to be made by 2025
ETNO (2021)	Cumulative impact of 150 bn EUR by 2027 in Europe.	~3 bn EUR ~0,5 bn EUR annually	Belgium's estimate based on its share of either mobile subscriptions (1,9%) or revenues (2,0%)
European Commission (2016)	Cumulative impact of 56 bn EUR by 2020 in Europe.	-	While this figure comes from a highly reputable reference, we consider this estimate to be obsolete and its representativeness is unclear as of today

Table 4-3: Reports quantifying investment for 5G [Source: Axon]

On top of the references above, the Bottom-Up model developed by Axon on behalf of BIPT (see Annex A for further details) estimates a total investment required in Belgium of 1,5 bn EUR by 2030, assuming that Orange and Proximus will fully operate under a RAN sharing agreement and that, therefore, only two 5G access networks will be deployed in the country.

Total 5G-related investment in Belgium will strongly depend on the deployment strategy adopted by the MNOs (e.g., two vs. three radio access networks deployed), and the regulatory conditions in place (e.g., the applicable NIR limits). Subject to these caveats, we believe that under the most favourable scenario for MNOs, the investment required

[73] ETNO – Connectivity & Beyond, cited above.

[74] Analysys Mason (2021). "Analysis of the costs and benefits of 5G geographical roll out in Europe: final report".

could be between 1,0 – 1,5 billion EUR, but that it could go up to the range of 2,5 billion EUR in a scenario of three access networks under the current NIR limits.

4.2. Environmental impact

This section examines the impact of the deployment of 5G in Belgium from four different perspectives, namely:

- Impact on electromagnetic radiation
- Impact on power consumption
- Impact on e-waste
- Impact on GHG emissions (GHG)
- Visual, noise and air pollution impact

The subsections below quantify the expected impact of 5G on each of these verticals.

4.2.1. Impact on electromagnetic radiation

As presented in Subsection 3.1.4, the regulations limiting the electromagnetic radiation coming from mobile installations existing in the different Regions of Belgium will play a relevant role in the deployment of 5G networks in Belgium. Considering that the existing regulations aim to ensure that the levels of electromagnetic radiations emitted by the operators are safe, one way to carry out this analysis is to review how operators can comply with these limits and regulations.

In this context, the regulations in the different parts of the country will affect this deployment in a different manner:

- **Brussels Region**: In this Region, the existing regulation sets a cumulative limit for each installation. In practice, this means that deployment of 5G capabilities may not be feasible in sites which are already near this threshold (which represent a non-negligible share of the sites currently available in Brussels). Thus, in Brussels, the deployment of additional sites may be required to enable 5G.

  The Bottom-Up model developed for this project (please see Annex A for further details) shows that, to ensure compliance with the limits in place in Brussels, only some configurations of sites (in terms of spectrum bands and technologies) will be able to include 5G capabilities:

Technology present in the site?			Can 5G be added to this site?
2G	3G	4G	
Yes	Yes	Yes	◔
Yes	Yes	No	◑
Yes	No	Yes	◑
Yes	No	No	◕
No	Yes	Yes	◑
No	Yes	No	◕
No	No	Yes	◕
No	No	No	●

Legend: ● High probability ○ Low probability

Table 4-4 : Compatibility of 5G with existing sites [Source: Axon]

As shown in the above table, in sites that concurrently provide all existing access technologies, adding 5G would likely push electromagnetic radiation over the existing regulated threshold. Therefore, an alternative workaround (e.g., deploying additional sites) would need to be found. This situation becomes less likely for sites where any (or some) of the existing access technologies are not installed. Considering that a recent study from the BIPT suggests that over 30% of the 4G sites in the Brussels Region have a moderate risk of saturation, we can safely state that, with the existing limitations in the Region, a non-negligible part of the sites will not be able to accommodate 5G and additional sites will need to be deployed.

However, it is worth noting that, under such a situation, even though the operators would have to make a relevant operational and financial effort to deploy 5G in Brussels, electromagnetic radiations would not be impacted.

On the other hand, should the NIR limits in the Brussels region be increased to similar levels to the ones proposed by the BIPT in its 2018 report "on the impact of the radiation standards in Brussels on the deployment of mobile networks", it would be possible to add 5G to most of the existing sites in Brussels.

In such a case, the suggested relaxation of the NIR limits would assume a 6-fold increase in the maximum non-ionising electromagnetic radiation received by citizens (increasing it to a total of 0,56 W/m^2). However, even after such an increase (which sounds significant), the non-ionising radiation emitted in the Brussels Region would still be well below the limits recommended by the ICNIRP and the EC, as the exhibit below shows:

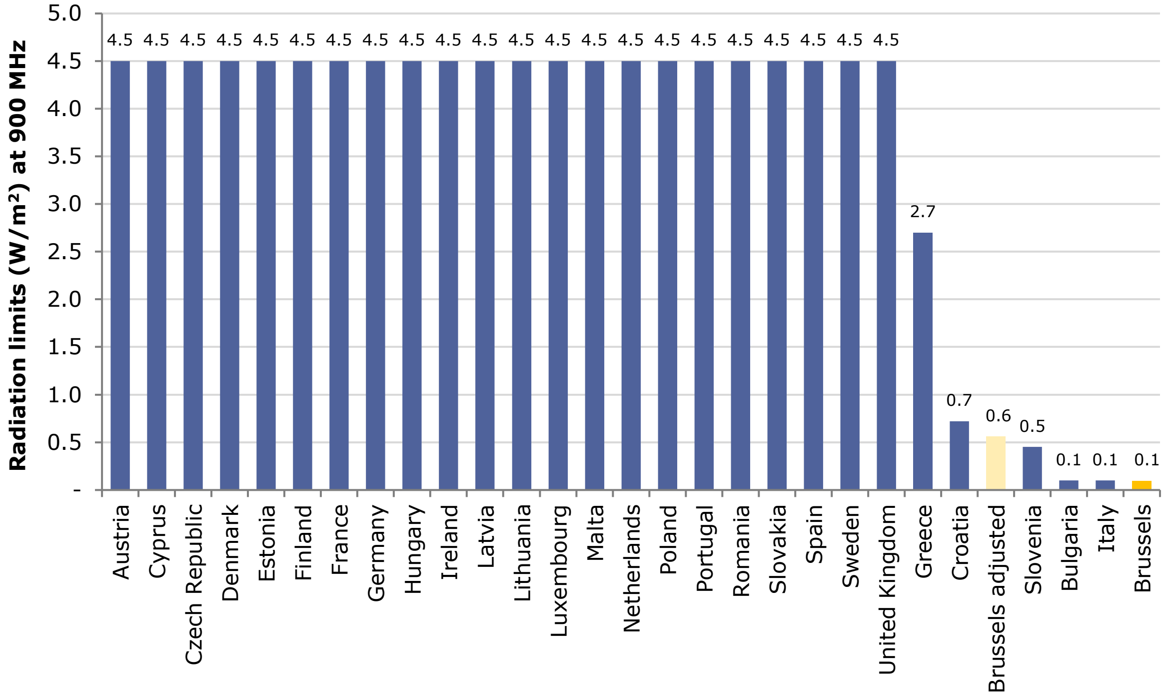

Figure 4-4: Comparison of radiation limits (at 900 MHz) in the European Union [Source: BIPT and Axon]

- **Flemish Region:** In this region, the regulation sets two main limits: i) a cumulative limit (similar to the one set in the Brussels region, albeit more relaxed) and ii) a limit measured on a per frequency band, per technology and per operator basis. In practice, the latter limit is always the most restrictive one for mobile operators. For this reason, as the deployment of 5G networks will fall under a separate limit, operators are likely to be able to deploy 5G through the existing sites, while complying with the existing regulation on the non-ionisation radiations.

  A potential concern in the Flemish Region lies in the deployment of the 3,6 GHz band. The large amount of spectrum available in this band entails higher electromagnetic radiation. In order to ensure compliance with the existing limits, operators may need to restrict the reach of sites employing this spectrum band.

  Despite compliance with the regulations on NIR, the deployment of a new technology in the existing sites is going to inevitably increase the power of the non-ionising radiations received by citizens by around 33%. However, in practice the new radiation would still be of ~ 0,57 W/m^2 [75], around 87% below the limits recommended by the ICNIRP and the EC[76].

In the process of preparing this report, the Flemish Region issued a draft decision to update the NIR limits. In its proposal, the overall limit remains unchanged (1,13 W/m^2), but the individual limit of 0,024 W/m^2 per antenna[77] is increased to 0,21 W/m^2 per operator[78]. If this draft decision is approved, the deployment of 5G would not affect the electromagnetic emissions in this Region as MNOs would be constrained by the overall limit imposed to them. Under this scenario, electromagnetic radiation would fall around 86% below the limits recommended by the ICNIRP and the EC.

- **Walloon Region:** In this Region, the regulations define a limit measured on a per technology and operator basis. As in the Flemish Region, this type of regulation does not represent a critical issue for 5G deployment, as the deployment of a new technology will fall under a separate limit. In this case, the same considerations as per the Flemish Region will apply. Therefore, non-ionising electromagnetic radiation is expected to increase by 33% with the advent of 5G, which in the case of Wallonia will imply a power of 0,29 W/m^2 [79], still ~94% below the limits recommended by the ICNIRP and the EC[76].

Another relevant aspect in terms of electromagnetic radiation in 5G networks has to do with the use of multiple-input multiple-output (MIMO) antennas, and beamforming techniques. Beamforming refers to the ability of antennas to target beams directly to the users using mobile services. Without beamforming, the antennas emit radio waves in a homogeneous pattern in the covered area.

The use of beamforming results in more intense radiation in a specific direction when the service is active, but for a much shorter duration, and overall much less intense radiation whenever the service is not active. For this reason, on average, for the same peak emitted power, 5G is expected to result in lower electromagnetic fields. While research in this area is still ongoing, some public entities, such as the Swiss Federal Office for the Environment

[75] Assuming two spectrum bands associated with 5G networks, and a total of eight antennas for each operator.

[76] Considering the ICNIRP thresholds at 900 MHz. The gap between the emissions and the ICNIRP's suggested limit would be broader if measured in higher frequency bands.

[77] Considering one antenna for each operator, technology and band.

[78] Regardless of the band and the technology.

[79] Considering four antennas (2G, 3G, 4G and 5G) for each operator.

(FOEN)[80], have started developing guidelines on the use of MIMO and antennas using beamforming. These guidelines suggest that peak emitted power in 5G with beamforming could be 8-10 times greater compared to not using this technique, without increasing overall electromagnetic radiations and thus without compromising existing regulations on electromagnetic fields.

Against this background, we consider that the impact of adaptative antennas on the overall electromagnetic radiation is probably neutral. The increase in emitted power, which will serve to increase spectrum efficiency and data rates, will not result in increased electric fields in the areas covered with 5G, as the increased emitted power will take place in much shorter bursts.

However, it is worth pointing out that, with the existing regulations in Belgium, which are based on peak power in all of the three Regions, operators may be unable to extract maximum benefits from beamforming technology. In our view, in order to exploit this technology's maximum potential, the existing NIR limits could include a correction factor that would take into account the effect of beamforming on electromagnetic radiation. Moreover, the consideration of beamforming and adaptative antennas should not only be considered in the calculation of the NIR limits, but also in the measurement methodology, as the radiation levels will differ significantly depending on the activity between the emitting base station and the receiving measurement device.

4.2.2. **Impact on power consumption**

Interest in 5G is coming from a diverse range of industries, and is driven by shared expectations that 5G networks will support substantially higher data rates, and offer an improved quality of service, security and flexibility. Up to now, this type of demand has been addressed through cutting edge transmission techniques, such as massive Multiple Input Multiple Output (MIMO) and mm wave (mmWave) bands, and by shifting computational power closer to the edge (i.e. to users) through advanced baseband processing units at the base stations. Such techniques will be intensified in a 5G environment.

5G networks are expected to open many new business use cases for operators (public and possibly also private). Among other advantages, 5G is expected to be far more power efficient per bit. However, its use in potentially millions of IoT/M2M devices could

[80] Link: https://www.emf.ethz.ch/fileadmin/redaktion/public/downloads/5_news/BAFU_Vollzugsempfehlung_Adaptive_Antennen_2021.pdf

significantly raise total energy consumption. As the ICT industry is already responsible for 10% of the world's energy consumption, energy-efficiency has become one of the key performance indicators (KPI) for ICT and will inevitably also affect 5G rollout and take-up. Therefore, various methods of enhancing power allocation and optimizing energy are being investigated for 5G.

The split is also reflected in the studies discussed below: their message differs significantly depending on whether they look at the expected impact of 5G **on total energy consumption** (typically for a period from 2020 to 2030), or from the perspective of its impact on **energy efficiency.**

Impact on total energy consumption

According to **InterDigital/ABI Research** (2020), 5G-related energy consumption is expected to increase by 160% from 2020 to 2030 mainly driven by IoT end-devices.

Eriscsson estimates that "[e]*nergy consumption is set to increase dramatically if 5G is deployed in the same way as 3G and 4G were. This is an important issue to address*" [...] "*Thanks to the 5G standard and our development efforts, it is possible to significantly reduce energy consumption. 5G, which is the most energy-aware standard, will allow the mobile system to use smart sleep modes more effectively*". Ericsson describes this as "breaking the energy curve" and illustrates this as follows:

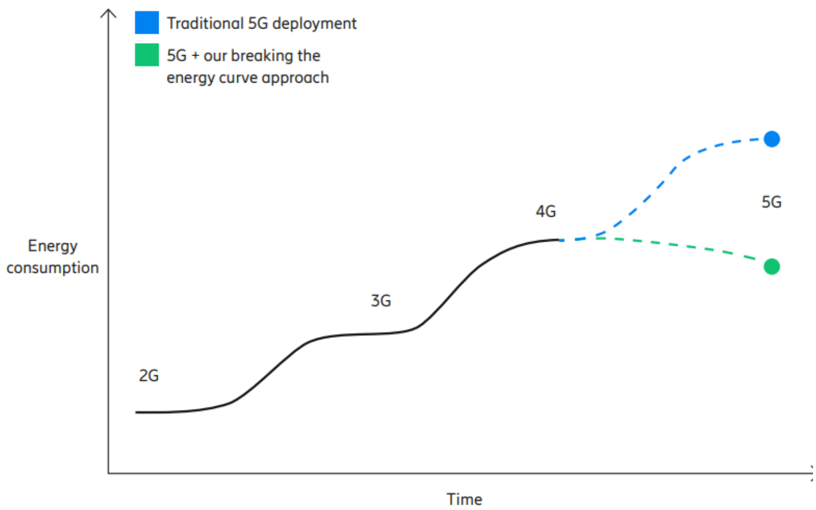

Figure 4-5: Ericsson's breaking the energy curve approach [Source: Ericsson]

Ericsson's suggested strategies to reduce energy consumption include the following steps:

- "Preparing the network", i.e., replacing existing network assets instead of simply adding new ones;

- “Activating energy-saving software”, which refers to energy saving features in the 5G network components, such as “micro-sleep” functions;

- “Building 5G with precision”, i.e., avoiding over-dimensioning hardware by considering the needs for a specific area, to save on energy and costs.

- “Operating site infrastructure intelligently,” including the use of artificial intelligence to operate site infrastructure.

451 Research argues that “*5G is widely expected to raise overall energy costs. Nearly all (94%) respondents indicated that 5G will raise overall energy costs. Given the prominence of energy as an overall percentage of opex, it’s clear that mitigation strategies will be critical to maintain 5G business case viability.* […] *Energy-saving tactics will be varied and address every layer, from intelligent networking equipment that enters sleep mode during idle time to use of artificial intelligence (AI) and new cooling techniques.*”

Climate Change News expressed a very negative view in 2017 for the whole industry: “*The communications industry could use 20% of all the world’s electricity by 2025, hampering global attempts to meet climate change targets and straining grids as demand by power-hungry server farms storing digital data from billions of smartphones, tablets and internet-connected devices grows exponentially.*”

However, if we look at the actual source of this conclusion,[81] it looks as if the above is just the very worst (and probably unreasonable) scenario, as illustrated below.

[81] Andrae, Anders, S.G (2017).

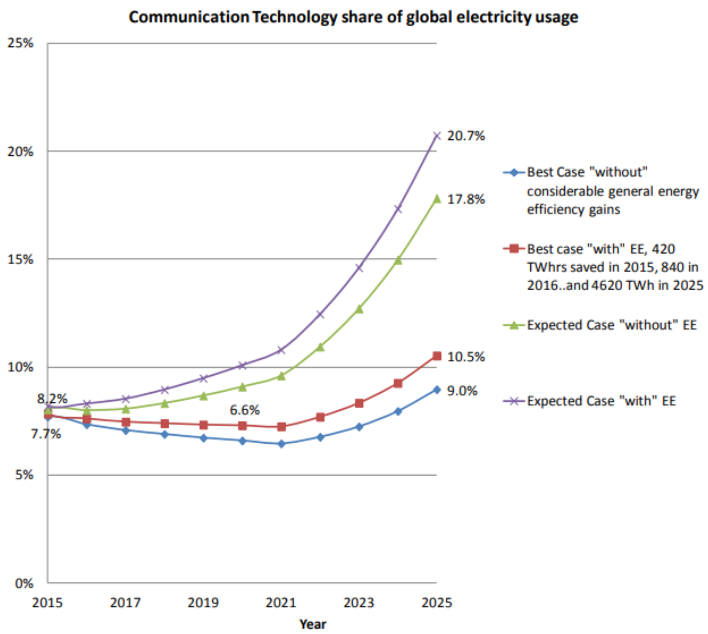

Figure 4-6: The share of ICT of global electricity usage: 2015 to 2025 with and without high global energy efficiency gains [Source: Andrae, Anders, S.G (2017)]

In a recent study, the **Shift Project**[82] (a carbon transition think tank) concludes that the case of 5G makes abundantly clear that new generations of technologies can make important innovations possible in certain sectors and for certain essential uses in society, but that these uses are driven by unsustainable dynamics in terms of energy consumption. The study refers to the view of the French High Climate Council (*Haut Conseil pour le Climat*) that the deployment of 5G is expected to increase the carbon footprint of digital technology by 18-44% by 2030, and GSMA's 2019 prediction that the costs associated with energy consumption for operators are expected to increase by several tens of per cent or even by a factor of 2 to 3, despite the improvement in unit energy efficiency.

Against such pessimistic forecasts, **Energy Realpolitik** suggests that "[a] *lot of hyperbole surrounds 5G. The energy consumption issue is being addressed by all of the major equipment manufacturers. Carriers can't afford massive, new power costs and will not deploy technology they can't afford to operate. The deployment time for large and complete 5G networks will not be overnight and what constitutes 5G isn't fully sorted out, but out of control energy consumption growth is not in the cards. That there could be innovation in how energy is harnessed and transmitted is a potentially important area for innovation. Our assumptions can and will change."*

82 Shift Project (2021).

To sum up, studies seem to agree on the principle that ICT, and 5G in particular will lead to an increase of total energy consumption. While quantified estimates tend to show a very significant increase (160% by 2030 or 20% of the world's electricity for ICT in general by 2025), other views suggest that the problem may turn out to be less acute, as it is in the industry's best interest to work continuously on innovative ways to reduce such extra energy consumption, even if the effect of this cannot be quantified in advance.

Impact on energy consumption per unit of traffic

Studies focusing on energy consumption per unit of traffic (e.g., Gigabits) rather on total consumption are arguably more reliable, as they can do without the great unknown of 5G overall take-up.

Nokia claims that "*5G networks are up to 90 percent more energy efficient per traffic unit than legacy 4G networks*".[83]

More cautiously, according to **Orange** "[w]*hile a 5G antenna consumes three times more energy on average today than a 4G antenna, this ratio is expected to drop to 50% by 2021 and 25% by 2022. Above all, for this energy consumption, a 5G antenna manages a bandwidth five times higher and can deliver a higher throughput to serve more users simultaneously […] Because they have integrated the energy-efficiency issue from the outset, 5G technologies are expected to divide the energy consumption per gigabit transported by a factor of 10 compared to 4G once they reach maturity by 2025, and then by a factor of 20 by 2030*".

Such energy efficiency, however, must still balance the negative effects of the dramatic increase of traffic through 5G, which may be an impossible task. As stated by the **Next Generational Mobile Networks (NGMN)** alliance: "*5G should support a 1,000 times traffic increase in the next 10 years timeframe, with an energy consumption by the whole network of only half that typically consumed by today's networks. This leads to the requirement of an energy efficiency increase of x2000 in the next 10 years timeframe.*"

Similarly, **Koziol**[84] comments that "*A 5G base station is generally expected to consume roughly three times as much power as a 4G base station. And more 5G base stations are needed to cover the same area.*"

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[83] Nokia (2020).

[84] Koziol, M. (2019).

Impact on total energy consumption + Impact on energy consumption per unit of traffic

There is, therefore, unanimity in the expectation of significant per unit of traffic (i.e., per unit of data) economies in energy consumption through 5G. The question, however, lies in the extent to which the expected increase in the volume of traffic and devices, as well as per antenna or other device unit consumption, could drastically outweigh any energy efficiencies per Gigabit.

Huawei argues that "[e]*nergy consumption per unit of data (watt/bit) is much less for 5G than 4G, but power consumption is much higher. In the 5G era, the maximum energy consumption of a 64T64R active antenna unit (AAU) will be an estimated 1 to 1.4 kW to 2 kW for a baseband unit (BBU).*"

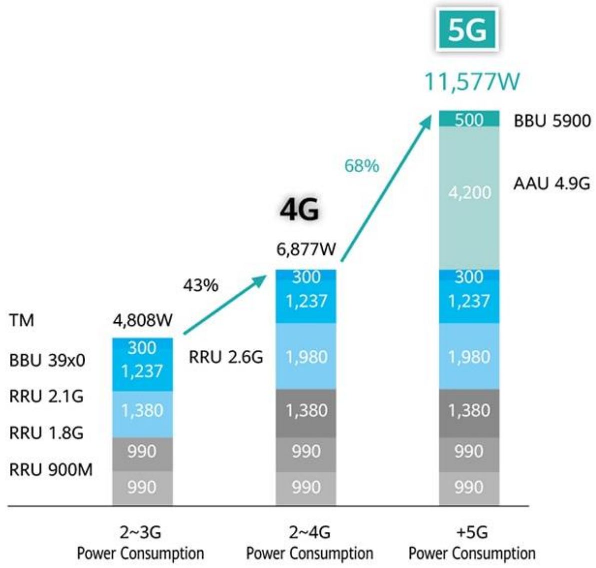

Figure 4-7: Typical maximum power consumption of a single 5G base station [Source: Huawei]

Further: "*The growth of power consumption by 5G networks will trigger growth in energy consumption in general. In China, for example, total power consumption by telecoms networks exceeds 50 billion kWh. Once 5G networks are deployed, the power consumption of telecoms networks in China will exceed an estimated 100 billion kWh, generating annual carbon emissions of 27.2 billion kg.*".

Conclusions on power consumption

Impact from the network

Some of the reports assessed suggest that 5G may be expected to increase the overall power consumption compared to the current situation due to the presence of additional active equipment and the steep growth of data traffic forecasted for the upcoming years.

In particular, data traffic is expected to grow by 25% between 2020 and 2026 according to Ericsson's mobility report. In a recent report prepared for the BIPT, [85] Capgemini also expects data traffic to grow by close to 25% per year between 2020 and 2030. However, when assessing power consumption, it is not only relevant to consider the additional number of assets to be deployed per access technology, but also their differences in terms of energy efficiency. For instance, the references reviewed conclude that 5G is expected to be 10 times more efficient (on a per-bit basis) than 4G. However, as different access technologies coexist in the same environment, this does not mean that energy efficiency of access networks as a whole will be 10 times better with, rather than without, 5G.

In the model developed in the context of this project, we have carried out several projections in terms of the evolution of network adoption of different technologies. According to the aforementioned Ericsson report, data traffic on 4G networks is expected to keep growing in the medium term (overall, a roughly 2-fold increase in 4G traffic is expected by 2026). However, its growth is expected to slow down over time as networks become congested and 5G gains more traction. For this reason, most of the data traffic growth is expected to come from 5G. Extrapolating the estimations provided by Ericsson to the current situation in Belgium, we obtain the following distribution of traffic between the different mobile access technologies.

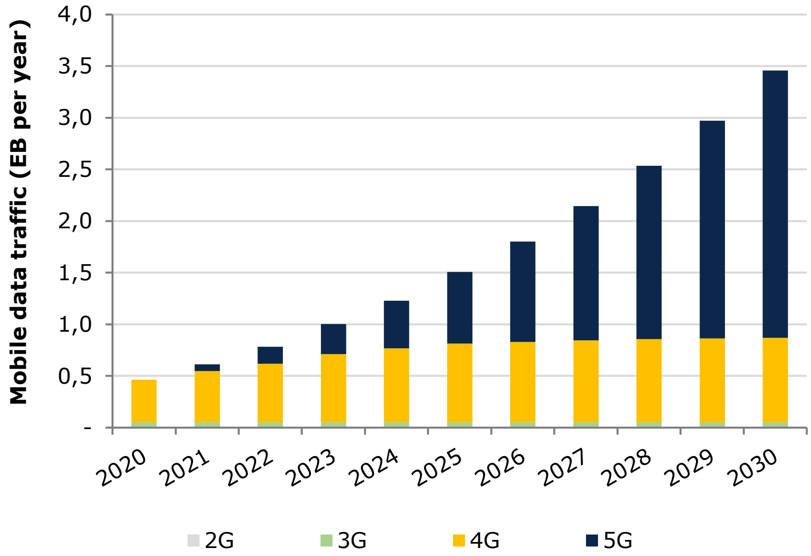

Figure 4-8: Data traffic evolution per access technology [Source: Axon]

The overall energy efficiency of the network will therefore be a blend of the energy efficiency of each of the access networks deployed. Based on these assumptions, we would

[85] Capgemini (2020)

expect a reduction of 70% in the power consumption per bit by 2030 if 5G is deployed in Belgium.

Figure 4-9: Comparison of the energy efficiency per bit in access networks with and without 5G [Source: Axon]

Considering the forecasted growth in data traffic (8-fold increase), and the expected distribution of traffic per technology by 2030, the overall network energy consumption in the access network would increase by 10-15% in 2030 compared to the situation in 2020.

However, a key aspect to consider in the assessment of the potential impact of 5G in terms of energy consumption lies in the forecasts for data traffic if 5G were not to be rolled out. Should the 5G network cease to exist, it is arguably true that some of the traffic expected to be handled by the 5G network would not "disappear" and would instead be handled by the existing access networks. For this reason, we consider reasonable to assume that if 5G were not to be deployed, data traffic would see anything from the 2-fold increase currently expected to take place in 4G networks when deployed along with 5G networks to the aforementioned 8-fold increase. Depending on the level of traffic, we would observe different levels of traffic consumption compared to the 5G scenario:

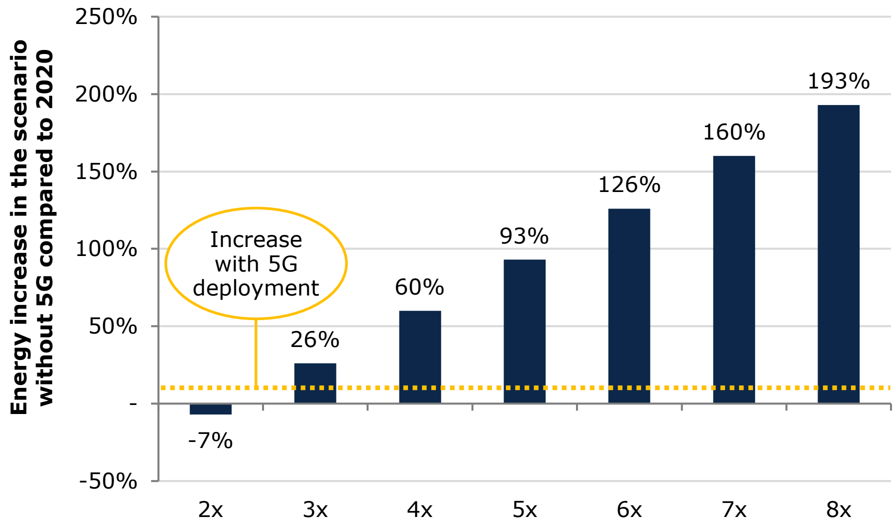

Figure 4-10: Energy increase in the access network in 2030 in scenarios without 5G, depending on 4G traffic forecasts compared to current consumption [Source: Axon]

We mainly observe that if one assumes that the lack of 5G deployment will not lead to additional traffic in 4G networks, the deployment of 5G will lead to a net increase in energy consumption. However, if we consider that 4G networks would indeed absorb part of the foregone 5G traffic, the overall energy might actually go up as compared to a scenario with 5G deployment. For instance, taking one of the middle scenarios, where the traffic in 4G networks experiences a 6-fold increase, the result we obtain is that the deployment of 5G would reduce, approximately, 50% of energy consumption by 2030.

As a result, from an access network perspective, it seems likely that the deployment of 5G networks will result in a (slight) increase in energy consumption compared to the current situation. However, when comparing a situation in 2030 with 5G against one without 5G, the impact of 5G will strongly depend on how much data traffic would grow by 2030 in the absence of 5G. Depending on the considerations adopted, 5G could arguably **decrease** energy consumption in RAN between 11% and 41%, compared to the consumption without 5G in 2030.[86]

Meanwhile, for core networks, it is expected that operators will need to deploy additional equipment to handle 5G networks and the increasing traffic levels. In this context, some reports (e.g., ABI Research, 2020) estimate that with the advent of 5G networks, energy expenditure in the core network will increase by up to 150% compared to current levels. However, once again, the impact on energy consumption by 2030 with and without 5G is

[86] Based on the scenarios where 4G data traffic is expected to increase by 3x and 5x by 2030.

much less clear, as it will also strongly depend on the estimates on 2030 traffic levels in the absence of 5G. As 5G data traffic efficiency in the core network is not expected to be substantially better than with 4G, assuming a 20% improvement in energy efficiency would imply that, depending on the data traffic growth without 5G, 5G could be argued to increase energy consumption in core networks by up to 50% or to decrease it by up to 15%.

The table below summarises the expected impact of 5G by 2030 on energy consumption on the supply side of the telecommunications sector:

Impact on supply	RAN	Core	Total
Impact on energy per NW section	-41% to -11%	-15% to +50%	
Weight[87]	85%	15%	
Total impact on energy	**-35% to -9%**	**-2% to +8%**	**-37% to -1%**

Table 4.5: Impact on energy consumption on the supply side of the telecommunications sector [Source: Axon]

This shows that, while energy consumption is expected to increase by 2030 compared to today, the deployment of 5G could decrease energy consumption in mobile telecoms networks by up to 37% compared to a scenario where 5G were not deployed. As mentioned above, the actual impact will largely depend on how much data traffic would grow by 2030 in the absence of 5G.

Impact from the users

In terms of demand of telecommunications services, 5G is broadly expected to bring the number of connected devices to a completely new level. Several studies have projected the number of connected devices to reach 20 billion, 50 billion or even 100 billion by 2030. Therefore, it could be argued that 5G may indeed have an important impact on energy consumption on the demand side of the business.[88]

As a result, in order to assess the impact on demand, we consider that the analysis should be broken down into two main components:

- The traditional business model of MNOs (voice and data services). In our view, we should not observe an increase in power consumption in this area, as devices with

[87] Based on the ABI Research's 2020 estimates.

[88] While the impact on demand could also be explored from the perspective of the new use cases 5G is said to enable, this is not discussed in this subsection as no reports have been found exploring this matter and, thus, its impact remains largely uncertain.

5G should consume similar energy levels compared to existing devices, and we do not expect any significant increase in the volume of devices in the market.

- New verticals for MNOs. As previously outlined, 5G is broadly said to drive the number of IoT devices significantly upwards, with some reports expecting even up to 100 billion connected devices by 2030. However, it is equally true that a large percentage of these devices may work with technologies other than 5G (e.g., Wi-Fi, Bluetooth, 4G NB-IoT), and it is thus unclear if 5G is actually going to be the key driver for any increase in the number connected devices. Some industry experts (e.g., Bubley –2021-) point out that most connected devices will be "normal" mobile broadband connections, not ultra-low latency, with 5G playing a key role only for important, but niche and rare, instances of IoT. In our view, even though 5G is expected to contribute to an increase in energy consumption in the demand side of the telecoms sector – as it will contribute, to some extent, to the growth in the number of connected devices – any quantitative estimate of this impact would be just a best guess with a massive margin of error.

4.2.3. **Impact on e-waste**

The mobile telecom industry's contribution to e-waste comes from two main areas: the supply side (mobile network deployment) and the demand side (SIM cards and devices).

Considering a total e-waste per capita generated in Belgium in 2019 of roughly 20.4kg[89], or 230 kilotons (kt) at national level, we explore below how 5G could impact these figures by assessing its direct contribution from the supply and demand sides of the business.

From the supply side, drivers of e-waste come from the concept of replacing existing network equipment with new generation technology, making them redundant. Such levels of e-waste are highly uncertain, as they will depend on, among other factors, the specific technical developments to take place up to 2030 as well as the reuse levels of this equipment (i.e., second-hand market). In any case, the decommissioning of equipment, such as the one used for 2G and 3G, is an ongoing process, and it is therefore difficult to assume the degree to which 5G deployment is its direct cause, even if the two coincide in time.

A worst-case rough calculation, however, indicates that the e-waste generation from the supply side driven by 5G is unlikely to be significant compared to the national total.

[89] Source: https://globalewaste.org/proxy/?publication=/v1/file/275/In-depth-review-of-the-WEEE-Collection-Rates-and-Targets-in-the-EU-28-Norway-Switzerland-and-Iceland.pdf

Assuming a total of 11,000 sites in Belgium (based on the BIPT's data), with up to 200kg of active 2G, 3G and 4G-related equipment in them (based on manufacturers' specification sheets), and no reuse of this equipment, replacing all "old" networks could arguably generate 2.2 kt of e-waste. This would be a one-off over the 10-years period studied, so the annual contribution would be, at the very most, to the tune of 220 tons, i.e., roughly 0.1% of the country's total. It is important to highlight that this would be a very worst-case scenario, as we expect any potential e-waste generation driven by 5G in the supply side to fall well below this estimate.

From the demand side, we assess below the expected contribution on e-waste that shall be expected to come from SIM cards and user devices:

- **SIM cards**: Considering the current number of SIM cards in Belgium (~10 million), a weight per SIM card of 0,2 grams and an average lifetime of 1 year, the maximum contribution to e-waste from SIM cards would be of just 2 tons a year. Therefore, compared to the total e-waste generation in Belgium, the impact on the number of SIM cards under any scenario is bound to be insignificant.
- **User devices:** Similarly, considering a total of ~10 million smartphones in Belgium, a weight per smartphone of roughly 180 grams (say 200 grams if the charger is included) and an average lifetime of 3 years, adds up to an annual contribution to e-waste of around 600 tons per year. While this is much more relevant than e-waste through SIM cards, any potential impact on user devices is also going to be negligible given total volumes of e-waste in Belgium.

Therefore, while 5G could have the potential to contribute to an increase of e-waste from SIM cards and user devices, this impact would be, at most, negligible, as it would not represent more than 0.25% of the total.

On the other hand, while the deployment of 5G could have a larger impact on e-waste generation through the new use cases it is going to enable (e.g., in the automotive or healthcare industries) this aspect of its impact has not been assessed in any public studies we are aware of, despite being talked about by the press in mostly negative terms. What is likely is that industry-based solutions, such as industrial IoT and connected vehicles will leave room for specific applications of a crossover of emerging technologies like IoT, AI and 5G connectivity, thus leading to an increase in the development of small sensors and devices, and heightening the potential for e-waste. However, what is less clear is how much this expected increase in e-waste should be attributed to 5G, rather than these complementary technologies, and whether wide-scale 5G deployment will be truly a key ingredient for their implementation. There is still insufficient research on the direct relationship between the growing IoT market and the arrival of 5G. Its potential contribution thus remains largely uncertain.

4.2.4. **Impact on GHG emissions**

The direct impact of 5G on GHG emissions will effectively be driven by two key components: 5G impact on power consumption, and 5G impact on e-waste. However, given the massive use of renewables by MNOs in Belgium (Proximus and Orange claim to use 100% renewable energy whilst Telenet uses 90%)[90], it can be reasonably estimated that the telecoms market currently produces, at most, 0.05%[91] of total GHG emissions in Belgium. Thus, we do not expect any potential increase in the energy consumed by mobile network operators driven by 5G such as to lead to a significant impact in the total GHG emissions in Belgium. Similarly, as no significant direct impact of 5G on e-waste is expected, its direct contribution on GHG emissions should be largely insignificant.

Notwithstanding the above, and in line with our conclusions on e-waste generation, the deployment of 5G could potentially have a relevant indirect impact on GHG emissions in Belgium. Nevertheless, no studies we are aware of have assessed such a potential indirect impact and its overall importance thus remains largely uncertain.

4.2.5. **Visual, noise and air pollution impact**

Mobile networks are moving away from older 2G, 3G and 4G towards a more efficient 5G technology which will deliver low latency, greater reliability, and increased network capacity and reliability. 5G technology will support services that require higher bandwidth (such as virtual reality), low latency (such as remote management) and high connection density through a number of sensors. In order to achieve 5G capabilities and infrastructure, an upgrade of the legacy network will be required, a macro densification (small cells and distributed antennas), a fiberisation of the network (FTTA and backhaul), and the usage of edge computing and network slicing.

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90 Sources: Telenet Sustainability Report 2019. Link : https://www2.telenet.be/content/dam/www-telenet-be/Corporate/Duurzaamheid/VerslagenDownloads/30062020_Telenet_SustainabilityReport_2019_ENG_final.pdf; Orange Sustainability. Link : https://corporate.orange.be/en/social-responsibility/sustainable-development; Proximus Sustainability. Link : https://www.proximus.com/sustainability/respecting-our-planet/net-positive.html.

91 Calculated using Telenet's total contribution to emissions as a basis for the wider market. Link : https://www2.telenet.be/content/dam/www-telenet-be/Corporate/Duurzaamheid/VerslagenDownloads/30062020_Telenet_SustainabilityReport_2019_ENG_final.pdf

Some of the major factors of 5G that may have an impact on the environment include:

- **Deployment of small cells**: Network densification through small cells plays an essential role in achieving 5G capabilities, such as arear traffic capacity or capacity per user. In high traffic areas, some operators plan to roll out 200 small cells per square km, and it is even estimated that this could increase to up to 1000 small cell per square km in environments, such as stadiums, with the requirement to support up to one million connections.[92]

  This high number of small cells could have a significant visual impact in areas with a high density of connections, within large urban centres. Actually, a report from the European Commission (SMART 2018-0017) concludes that the main issues in granting permits for base stations are the protection of public health and a coherent visual landscape in terms of "aesthetics".

  In order to address both of these concerns, Article 57 of the EECC titled "Deployment and operation of small-area wireless access points" states that "*competent authorities may require permits for the deployment of small-area wireless access points on buildings or sites of architectural, historical or natural value protected in accordance with national law or where necessary for public safety reasons*".

  Therefore, although there is a growing trend towards densification due to increasing traffic, there is sufficient regulation to minimize the visual impact and to evolve towards small cells perfectly integrated into cities.

- **Fiberisation:** 5G capabilities and features need a fibre backhaul infrastructure to meet the new technology's specific requirements (fibre can transmit data faster and over longer distances while reducing energy consumption and waste), substituting existing microwave technology. The construction of such networks will cause temporary noise pollution, and construction vehicles will cause a temporary traffic disruption leading to an increase in the air pollution. However, such levels will be no greater than standard construction projects that take place daily. Notwithstanding the above, there are only a few microwave infrastructures in Belgium to be replaced and therefore minimal additional fiberisation will be required.

[92] Source: European Commission staff working document on small-area wireless access points. Link : swd-2020-0139-en.pdf (uni-mannheim.de)

As such, even though 5G adoption will increase the number of kilometres of fibre deployed, it will not represent a new significant environmental impact on top of the ones already observed in connection with the existing infrastructure.

- **Edge computing.** Edge computing is a necessary component of 5G for many advanced use cases, especially those that are mission critical and require very fast transfer and processing of data. This means edge computers will need to be deployed in key sites where use cases take place. This can be a potential problem for visual pollution, adding more infrastructure close to where people are, e.g., on the street. However, unlike small cells, edge computers can be hidden units that work like local servers. It is only proximity that matters.

  In terms of GHG emissions, edge computing can in fact have a positive impact due to a reduced need for full network use, instead localising network, and removing the burden on data centres. Such effect will make a negligible difference to the carbon emission of the existing MNOs since they are all running at, or close to, 100% renewable energy. As such, edge computing can be considered to have a negligible effect on the wider environment.

It can be therefore concluded that the overall visual impact of 5G rollout is unlikely to be significant, thanks to existing framework regulation at an EU level, which will force operators to use techniques for the concealment and proper integration of small cell equipment in the urban environment. It will be even easier to conceal any edge computers used in 5G network. As for any works required for fiberisation and other network upgrades, these may add to noise and air pollution locally and temporarily, but not at a level exceeding common public works.

4.3. Conclusions

To recapitulate, the following conclusions can be drawn on the expected economic and environmental impact of 5G in Belgium:

- Most reports reviewed estimate that 5G will contribute between 4 and 6 billion EUR to the Belgian economy (or 0.8% to 1.2% of GDP) by 2030.
- 5G is also projected to have a positive impact on employment – between 40,000 and 80,000 jobs by 2030, or an additional 1% to 2% to current employment figures. These should be mostly driven by developments in verticals using 5G rather than directly in the telecoms sector.

- While relevant studies tend to suggest a positive impact on Belgian operators' revenues through 5G, albeit at drastically different rates, we believe 5G is more likely to leave MNOs in an uncertain position, with their ability to secure revenues being largely dependent on their vision and ability to capture downstream market opportunities enabled by 5G.

- Based on existing studies and the results of our bottom-up model, 5G rollout in Belgium is expected to require investments in the order of 1.5 bn EUR if Orange and Proximus operate under a RAN sharing agreement and favourable regulatory conditions, but up to 2.5 billion in a scenario of three access networks, under the current NIR limits.

- In terms of impact on electromagnetic radiation, the Brussels Region will likely have a choice between increasing NIR thresholds or forcing operators to deploy additional sites, if at all feasible. If the regulations are changed to the levels suggested by the BIPT in 2018, radiation exposure will be increased by up to six times (to 0,56 W/m^2) but still be about 88% below the limits recommended by the ICNIRP and the EC. In Flanders and Wallonia, under the existing regulations, 5G deployment should increase radiation exposure by about 33% (to 0,57 W/m^2 in Flanders and 0,29 W/m^2 in Wallonia), but this will still be well below the limits recommended by the ICNIRP and the EC (by 87% for Flanders and 94% for Wallonia[93]). If the new proposal of the Flemish Region (April 2021) to update the NIR limits is taken forward, the deployment of 5G would not have any impact on electromagnetic radiations in this Region (while these being 86% below the limits recommended by the ICNIRP and the EC).

- 5G deployment is likely to increase the current energy consumption levels, even though it will bring significant improvements in terms of energy efficiency per bit. However, its impact as compared to a long-term hypothetical situation with no 5G deployment is much less clear, as this will strongly depend on how the telecommunications market would likely evolve in terms of data traffic growth or adoption of IoT devices, among others, in the absence of 5G. Our estimates suggest that, depending on the considerations adopted, the deployment of 5G could decrease energy consumption in mobile telecoms networks by up to 37% compared to a scenario where 5G were not deployed. Its impact on demand (i.e. end-user and IoT

[93] Considering the ICNIRP thresholds at 900 MHz. The gap between the emissions and the ICNIRP's suggested limit would be broader if measured in higher frequency bands.

devices), albeit most likely resulting in more energy consumption, is too uncertain to be quantified.

- The impact of 5G on e-waste is expected to be negligible (below 0.25% of total e-waste), at least as regards the most directly affected sources of e-waste. There are no systematic studies we are aware of quantifying reliably the wider impact on e-waste generation of the new use cases 5G is going to enable in the economy at large.

- Thanks to the massive usage of renewables by mobile network operators in Belgium, any potential increase in energy consumption is unlikely to lead to a noticeable increase in GHG emissions in the country. However, as for e-waste, the potential impact that the new use cases to be enabled by 5G may have on GHG emissions remains largely uncertain.

- Visual impact through the deployment of small cells and edge computers used in 5G should be minimal, given the regulatory framework in place. Works for the fiberisation and upgrades of the existing networks are unlikely to contribute to excessive noise and air pollution, beyond the level of common public works.

On the whole, and despite uncertain key variables (number of networks deployed, NIR limits and other regulatory components, response of telcos and the industry etc.) the overall impact of 5G on the economy is expected to be fairly positive, even if the share of telcos in such economic benefits remains uncertain and largely dependent on their strategy. The environmental impact is expected to be modest to minimal, especially as the current NIR thresholds in Belgium, and Brussels in particular, are particularly strict, leaving room for a more relaxed regulatory approach, if necessary, but still well below the limits recommended by ICNIRP and the EC. Similarly, 5G could have a positive effect on energy consumption by 2030 compared to a scenario where it was not deployed.

5. Assessment of the operational feasibility and implications of a new entrant in Belgium

This section examines the extent to which, with or without a transition to 5G, the entry of a 4th MNO in Belgium is operationally feasible, its likely consequences for the country's DESI indicators and its expected economic and environmental impact.

The discussion draws lessons from relevant international experience in other EU Member States and their relevance, if any, in light of the particularities of the Belgian telecommunications and regulatory landscape, and potential market entry scenarios. As discussed already, the main such particularities include the strict NIR regulation in the three Regions and the market structure and financials of the Belgian mobile industry.

Accordingly, the potential market entry scenarios we examine depend on whether:

- The current NIR limits will remain unchanged or be increased, along the lines proposed by the BIPT;
- The new entrant will be expected to roll out its own network infrastructure or be able to benefit from an active network sharing agreement with one of the existing MNOs.

For the economic impact, in addition to examples from international experience and conclusions drawn from relevant literature, our analysis relies on:

- inputs from the BIPT regarding operators' revenues and costs;
- a baseline scenario we have defined, reflecting the expected natural evolution of the Belgian market with only 3 MNOs and our assumptions on APRU, subscriber evolution, network OpEx and depreciation, and direct/retail/G&A costs;

For the environmental impact, our analysis is based on different scenarios for the future NIR regulation, and takes into consideration the hypotheses we have discussed for 5G in Subsection 4.2.

5.1. Impact of 4th MNO on DESI indicators

In order to identify the potential impact of market structure on the previously discussed DESI indicators (see Subsection 3.1.1), we have assessed the average score per indicator of the countries with 3 and 4 MNOs.

The results obtained are presented below:

Operator	1c1 4G coverage	1c2 Mobile BB take-up	1c3 5G readiness	Mobile broadband price index
Avg. score of countries with 4 MNOs (avg. rank for prices)	8,35	4,14	3,54	10,09
Avg. score of countries with 3 MNOs (avg. rank for prices)	8,54	3,83	3,62	17,35
R2[94] between score and # of MNOs	0,05	0,01	0,00	0,19
% of countries with 4 MNOs and a top-half score	45,5%	45,5%	36,4%	81,8%
% of countries with 3 MNOs and a top-half score	52,9%	52,9%	58,8%	29,4%
R2 between top/bottom half countries and # of MNOs	0,01	0,01	0,05	0,26

Figure 5-1: Comparison of results in markets with 3 vs. 4 operators [Source: Axon]

The results obtained suggest that the market structure has virtually no influence on the countries' score with regards to DESI 1c – i.e., mobile broadband and its sub indicators. The results from the two perspectives adopted (average score and relative ranking) do not seem to vary significantly between countries with 3 vs. 4 MNOs.

On the other hand, we acknowledge that, in terms of prices, the average rank of countries with 4 MNOs is noticeably better than that of countries with 3 MNOs. Moreover, it is particularly noteworthy that 82% of the countries with 4 MNOs fall amongst the top half of the rank, while this is only the case for 30% of the countries with 3 MNOs. While the correlation expressed in R2 is weak, this still suggests a possible relationship between the number of MNOs in a market and the level of retail prices. However, this analysis is

94 Coefficient of determination ("R squared").

insufficient to elucidate if the relationship between these two variables is causal or just casual. More on this is discussed in the subsections that follow.

5.2. Economic impact

In line with the distinction drawn earlier, in our assessment of the economic impact of 5G (Subsection 4.1), we shall discuss both the likely direct impact of a 4th MNO entry on the Belgian telecoms sector and its indirect impact on the Belgian economy in general. As will be seen, while the first may be easier to quantify, the second is at least potentially more important and positive, outweighing any (limited) negative effects expected for the "traditional" telecoms sector.

5.2.1. **Impact on the telecommunications market**

The first part of our assessment of 4th MNO's economic impact focuses on its direct impact on the "traditional" telecommunications sector. Our analysis starts with lessons drawn from relevant recent literature and experience gained in selected other EU Member States (Spain, France and The Netherlands). We will then undertake a high-level business case assessment of a 4th MNO market entry's impact on the Belgian mobile sector's financials.

It should be noted that the revenues considered here are limited to "traditional" telecoms market revenues. New revenue streams generated from 5G use cases and flowing to telecoms operators are too uncertain to estimate at this stage, especially in connection with the additional layer of variables associated with a 4th MNO entry. In any case, and unless stated otherwise, our analysis of a 4th MNO entry remains "agnostic" as to whether and when this entry would be combined with a transition to 5G.

Preliminary thoughts on the impact on retail prices

As discussed in Subsection 3.2, there is rich literature on the impact of new entrants (or mergers) on retail prices. The table below sums up the conclusions reached in the main reports/articles written to date that have explored any correlation between market structure and retail consumer prices:

Reference	Long term impact on prices (%)	Focus of analysis
Ofcom (2016)	↓ 17,2% - 20,5%	Considering a market with 4+ MNOs and a disruptive firm.
Genakos et al. (2018)	↓ 4% - 7%	Post-merger analysis from 4 to 3 MNOs.
Li and Lyons (2012)	↓	Post-merger analysis from 4 to 3 MNOs.

Reference	Long term impact on prices (%)	Focus of analysis
Csorba and Pápai (2015)	↓	Post-merger analysis from 4 to 3 MNOs.
Aguzzoni et al. (2015)	↓ 9% - 13%	Post-merger analysis from 5 to 4 and from 4 to 3 MNOs.
RTR (2016)	↓ 33% - 47%	Based on an ex-post assessment of H3G and Orange Austria's merger
BWB (2016)	↓ 12%	Effect of H3G/Orange and TA/Yesss! mergers in Austria
Wellmann (2019)	↓	Study on competition for 48 MNO from 14 European countries between 2011 and 2016
Berne et al. (2019)	↓ 11%	Entry of Free in the French market
OECD (2014)	↓ 27%	Entry of Free in the French market
BEREC (2018)	↓ 27%	Post-merger analysis from 4 to 3 MNOs.
Abate et al. (2020)	= Inconclusive evidence	Analysis on 29 European countries between 2011 and 2018
Frontier Economics (2015)	= No relationship found	Post-merger analysis from 4 to 3 MNOs in the EU, US and Australia
WIK (2015)	= No relationship found	Comparisons in 8 European and 4 non-European countries
GSMA (2018)	= Inconclusive evidence	Trends from 2012 to 2015 for 500 MB prepaid and postpaid tariffs in Central and South America
Affeldt and Nitsche (2014)	↑ 10%	Market entry of a 4th new MNO in European countries from 2003 to 2012. Only impact on voice services is assessed.
Houngbonon (2015)	↑	Based on Free's entry in France and a 4 to 3 merger in Austria
Aimene et al. (2021)	↓ 17% data unit price ↑ 22% voice unit price	Post-merger analysis from 4 to 3 MNOs in Austria, Germany, Ireland and Norway

Table 5-1 : Summary of the conclusions reached in literature on the long term impact of a 4th MNO on retail consumer prices [Source: Axon]

A few noteworthy conclusions to be drawn from the above are worth summarizing here:

- The references consulted have reached a range of conclusions, from arguing that a 4th MNO would bring down prices by as much as 47% to considering that prices could go up by up to 10%, with others finding no relationship between market structure and retail prices.

- At a very high level, it may look as if industry-originated studies tend to point to price increases as a result of a 4th MNO, while regulator-originated studies tend to point to the opposite finding. This suggests that the outcomes obtained are highly dependent on the assumptions and approach considered for the analysis.

- This all points to the complexity of properly assessing the likely impact of a 4th MNO on retail prices.

- For some, presumably good, reason (we are not aware of), all the studies/reports we have identified in the public domain have focused on assessing the impact on prices rather than on ARPU or revenue. This may be a double-edged sword: although. a decrease in prices definitely contributes to enhancing consumer surplus, these studies do not shed light on whether the price movements come as a result of larger bundles (i.e., with more data) – with the monthly bill being the same, independently of whether the customer makes use of the extra traffic or not – and therefore, constant ARPU, or if they have actually led to an ARPU reduction.

  Additionally, it is worth highlighting the complexity of accurately assessing impact on prices, as markets are heavily driven by bundles of multiple services, which tend to vary frequently (in terms of data/voice allowances and price) over time. Even if price baskets are considered, there is an important risk of the outcomes being influenced by natural and ephemeral market developments or even deliberate choices in a mix that favours the preferred outcome, rather than a market structure as such.

Even if the analysis in subsection 5.1 shows a relationship between the number of MNOs in a market and the retail prices in place - with 4 MNO markets enjoying, on average, lower retail prices – it has not been possible to conclude reliably whether this relationship is casual or causal.

Accordingly, in order to shed light onto these estimates and assumptions from a different angle, we have assessed the evolution of the mobile sector's revenues and subscribers (and, thus, ARPU) before and after the entry of a 4th MNO in a European market, based on the data available in the ITU WTI database 2020.

Our analysis has focused on three countries, in which a market entry took place several years ago, sufficient to allow for a long-term impact assessment:

- **Spain**, with the entry of Yoigo (now MásMóvil) in 2008.

- **France**, with the entry of Free in 2012.

- **Netherlands**, with the entry of Tele2[95] in 2012.

For each of these countries, we have assessed how the total mobile market revenues and subscribers behaved five years before and after the entry of a 4th MNO and compared it with the trend registered in other EU countries. The results of our analysis are provided below:

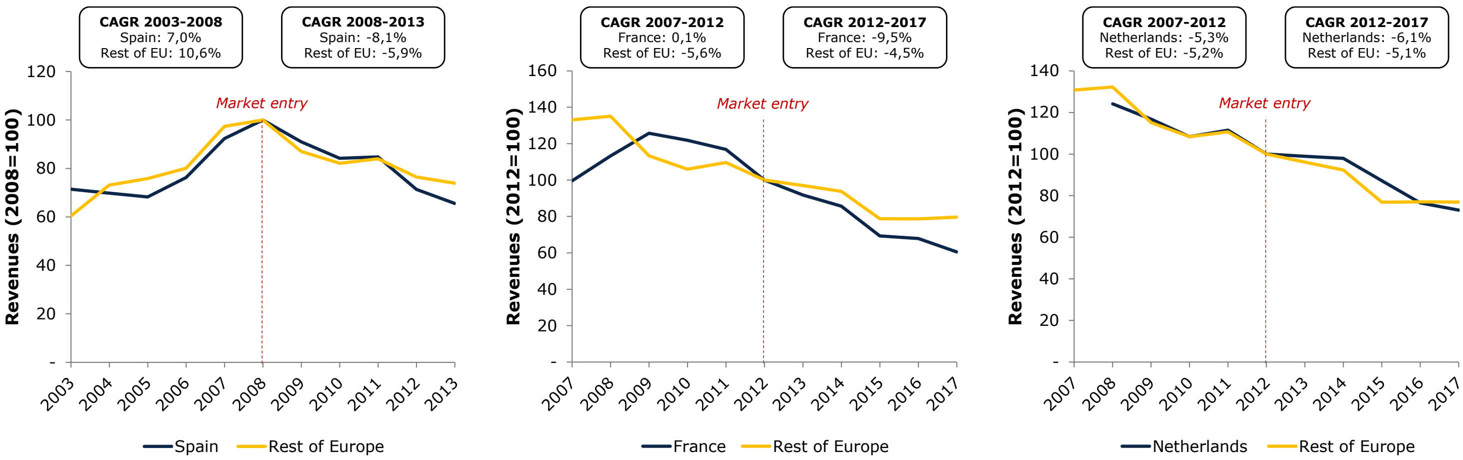

Figure 5-2: Evolution of mobile revenues before and after the entry of a 4th MNO in Spain, France and the Netherlands [Source: Axon based on data from the ITU's WTI Database 2020]. *Note: Historical growth for France is considered from 2009, as the sudden growth in revenues presented in the ITU's indicator just before is not considered to be fully representative.*

Comparing the difference in the revenues' growth before/after the market entry in each of these countries with the rest of Europe, we may draw some relevant conclusions on the impact of a 4th MNO on market revenues. The results obtained are presented below:

Reference	Impact on revenues after 5 years (%)[96]
Spain	↑ 17,2%
France	↓ 10,4%
Netherlands	↓ 8,8%

Table 5-2: Axon's estimated impact on revenues as a result of the entry of a 4th MNO [Source: Axon based on data from the ITU's WTI Database 2020]

95 Tele2 was later acquired by T-Mobile in January 2019.

96 Calculated as (growth(country x) after market entry - growth(country x) before market entry) - (growth(rest of Europe) after market entry - growth(rest of Europe) before market entry)

As part of this analysis, we have observed that the conclusions are highly dependent on the timeframe selected. For instance, the results considering a timeframe of 3 or 4 years (before and after the entry of a 4th MNO) would be noticeably different, not only in terms of the materiality of the impact, but also of its direction. Therefore, while it is true that, in the case of France, the outcomes are more constant over time, suggesting a stronger relationship between the entry of a 4th MNO and market revenues, in the case of Spain and the Netherlands this situation is not so obvious.

Additionally, and for a better grasp of the impact on ARPU, we have assessed the impact of a 4th entrant on mobile penetration (and, implicitly, the number of subscriptions). The results for the same set of three countries are shown below:

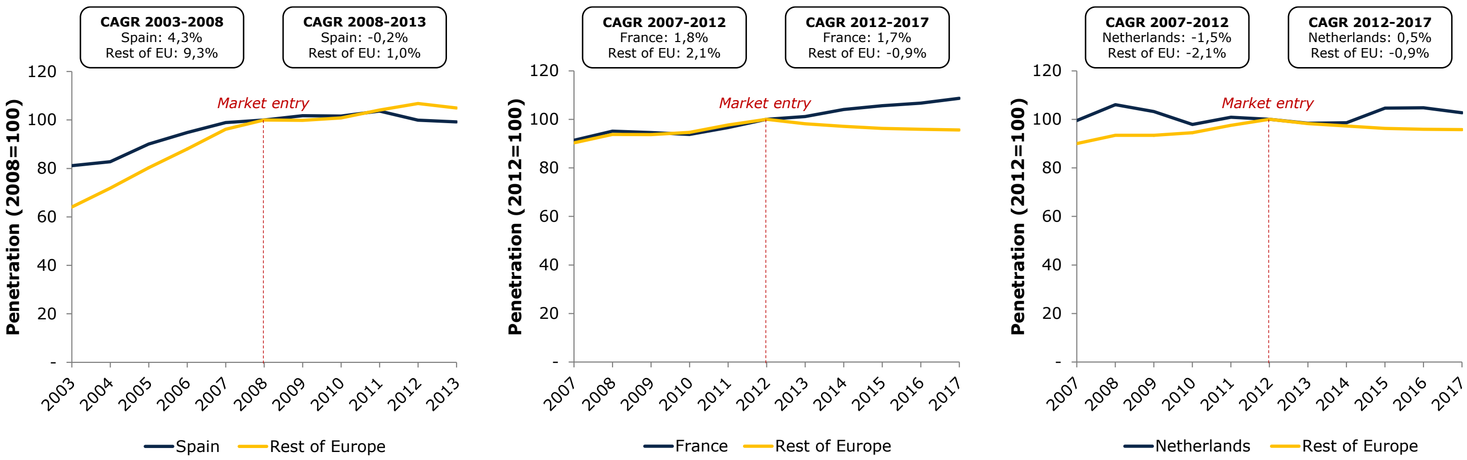

Figure 5-3: Evolution of mobile penetration before and after the entry of a 4th MNO in Spain, France and the Netherlands [Source: Axon based on data from the ITU's WTI Database 2020]

Again, as regards revenues, the entry of Free in the French market seems to have had the clearest impact on penetration among the three countries studied. We provide the quantified impact on penetration below, in the format we have also used for the revenues:

Reference	Impact on penetration after 5 years (%)
Spain	↑ 27,2%
France	↑ 14,3%
Netherlands	↑ 17,6%

Table 5-3: Axon's estimated impact on penetration as a result of the entry of a 4th MNO [Source: Axon based on data from the ITU's WTI Database 2020]

The conclusions in terms of penetration are somewhat clearer, with all countries assessed pointing to an expected positive impact of between 15-25% in the subsequent five years.

However, it is not possible to conclude whether the behaviour of these new subscriptions is equivalent to the rest or if they are likely to be the result of multi-SIMs, and thus exhibit lower usage patterns (and a smaller contribution to revenues).

Assuming all these subscriptions actively contribute to the generation of traffic, we present below the expected impact on ARPU:

Reference	Impact on ARPU after 5 years (%)
Spain	↓ 7,9%
France	↓ 21,6%
Netherlands	↓ 22,4%

Table 5-4: Axon's estimated impact on ARPU as a result of the entry of a 4th MNO [Source: Axon based on data from the ITU's WTI Database 2020]

To wrap up, based on the outcomes of the different studies reviewed and our own analysis of the recent experience in other European markets that have witnessed the entry of a fourth MNO over the last fifteen years, it may be expected that the entry of a 4th MNO in an average market:

- **May have an uncertain impact on "traditional" revenues**, which will highly depend on the nature of the 4th MNO and the strategy adopted by the different market players. Based on these considerations, total market revenues **could either go up or down by around 10% after five years**.
- Is likely to generate an **increase in the number of subscriptions by 15-25%**.
- As a result, **ARPU would likely decrease by around 10-20%** compared to a base case with 3 MNOs, although it is uncertain whether this observation could be a result of cheaper retail tariffs or lower consumption patterns of the new subscriptions (or, most likely, a mix of the two).

Expected impact on the Belgian mobile sector's financials

In order to estimate more precisely the potential impact of a 4th MNO on the overall Belgian mobile telecoms sector, we have carried out a high-level business case assessment of its likely long-term implications by 2030. In particular, the analysis performed aims at assessing the impact of a 4th MNO on revenues (including prices), costs and profits.

To perform this analysis, we have relied on the data provided by BIPT on revenues as well as on the information on costs that could be extracted from the financial statements of the three MNOs currently operating in the Belgian market. This initial information is reproduced in the table below:

Parameter	2017	2018	2019	Notes
ARPU (EUR/month)	15	15	15	Based on data provided by BIPT
#of subscribers (million)	12	12	12	Based on data provided by BIPT
Revenues (M EUR)	**2,137**	**2,135**	**2,186**	
Network OpEx (M EUR)	513	570	580	Based on Orange's operational costs as a % of mobile revenues and considering the cost distribution per category of Orange and Telenet
Direct costs (M EUR)	517	520	529	
Retail costs (M EUR)	217	226	232	
Administrative costs (M EUR)	383	341	348	
Depreciation (M EUR)	406	406	420	Based on Orange's depreciation as a % of mobile revenues
Total costs (M EUR)	**2,036**	**2,063**	**2,110**	
Operating profit (M EUR)	**100**	**73**	**77**	
Operating profit (% revenues)	**4.7%**	**3.4%**	**3.5%**	

Table 5-5: Revenues and estimated cost structure of the mobile market in Belgium [Source: Axon based on data provided by BIPT and the financial statements of the three MNOs]

Note: *While we are confident about the representativeness of the revenue-related figures presented above, as these were directly provided by BIPT, we acknowledge that the cost-related figures are subject to a number of hypotheses, as no mobile-specific cost-related information is available for the three MNOs. The cost-related figures presented above are likely to represent a worst-case scenario, as they are mostly based on Orange's financial statements, the only operator who may be only marginally capable of benefiting from the economies of scale of a fully integrated fixed+mobile operation. As a result, when evaluating the results reached in this section, we also provide insights on how these would likely look if a more conservative assumption were to be adopted in terms of the previous cost-estimates.*

As the operational strategy to be followed by the 4th entrant in terms of network deployment, as well as the regulatory framework applicable at the time of its entry are unclear, we have considered four potential market entry scenarios, as described below:

1	CURRENT NIR LIMITS + OWN INFRASTRUCTURE	▸ The new MNO deploys its own mobile infrastructure in the access, transmission and core networks, with limited room for site or mast sharing. ▸ The current NIR limits applied in the three regions of Belgium are preserved.
2	RELAXED NIR LIMITS + OWN INFRASTRUCTURE	▸ The new MNO deploys its own mobile infrastructure in the access, transmission and core networks, with limited room for site or mast sharing. ▸ The NIR limits are increased to around twice the current levels (e.g. a value of 14.5 V/m in the Brussels Region).
3	CURRENT NIR LIMITS + ACTIVE SHARING	▸ The new MNO purchases spectrum that otherwise would be allocated to the current three MNOs to be used in the access sites where it has reached a RAN sharing agreement. It does not deploy access equipment, but does deploy its own transmission and core networks. ▸ The current NIR limits applied in the three regions of Belgium are preserved.
4	RELAXED NIR LIMITS + ACTIVE SHARING	▸ The new MNO purchases spectrum that otherwise would be allocated to the current three MNOs to be used in the access sites where it has reached a RAN sharing agreement. It does not deploy access equipment, but does deploy its own transmission and core networks. ▸ The NIR limits are increased to around twice the current levels.

Table 5-6: Definition of the four alternative market entry scenarios considered for the 4th MNO [Source: Axon]

Moreover, we have defined a baseline scenario, aimed at reflecting the natural evolution of the Belgian market under the current market structure (i.e., with 3 MNOs) in order to have a clear reference of comparison with the impact of a 4th entrant into the market by 2030. The table below describes the assumptions adopted with regard to the expected evolution of the main financial KPIs sector-wide from 2019 (see Table 5-5 above) to 2030:

	Δ ARPU	Δ Subs.	Δ NW OpEx	Δ Direct c.	Δ Retail c.	Δ G&A costs	Δ Deprec.
0 3 MNOS	+14%	+2%	+5%	+13%	+10%	-10%	+9%

Table 5-7: Expected growth of the different financial KPIs from 2019 to 2030 in the baseline scenario [Source: Axon]

A brief description of the assumptions underpinning these estimates is presented below:

- **ARPU**. The ARPU evolution for the base case has been estimated based on its historical growth in Belgium, which essentially reflects a CPI-driven inflation (i.e., limited to no growth in real terms). As previously indicated, only the impact on "traditional" revenues are considered throughout this exercise.

- **Subscribers**. Estimated based on the average of the projected number of mobile subscribers according to historical trends and the expected population growth trends for Belgium. As for the previous variable, only subscribers of "traditional" telecommunication services are considered in this exercise.

- **Network OpEx and Depreciation**. The likely evolution for these, mostly network-related, costs has been extracted from the results of the Bottom-Up modelling exercise carried out - see Annex A for a brief description of the main characteristics and considerations of this exercise.

- **Direct costs, retail costs and G&A costs**. The estimates made for the evolution of these variables are based on a regression analysis of their trends between 2017 and 2019.

A similar set of hypotheses has been designed for each of the four potential market entry scenarios described above. For the sake of clarity, the figures presented in this table reflect the expected difference of each of these KPIs by 2030 between the baseline and each market entry scenario (e.g., the 37-47% presented under "Δ NW OpEx" for scenario 1 implies that total market network opex in 2030 is expected to be between 37% and 47% higher in the event of a 4th MNO deploying its own network with the current NIR limits than in a scenario with 3 MNOs).

	Δ ARPU	Δ Subs.	Δ NW OpEx	Δ Direct c.	Δ Retail c.	Δ G&A costs	Δ Deprec.
1 CURRENT NIR + OWN INFR.	-22% to -17%	+14% to +19%	+37% to +47%	0% to +10%	+5% to +15%	-15% to -5%	+37% to +47%
2 RELAXED NIR + OWN INFR.	-22% to -17%	+14% to +19%	+30% to 40%	0% to +10%	+5% to +15%	-15% to -5%	+33% to +43%
3 CURRENT NIR + ACTIVE SH.	-13% to -8%	+10% to 15%	+14% to 24%	-3% to +7%	0% to +10%	-10% to 0%	+22% to +32%
4 RELAXED NIR + ACTIVE SH.	-13% to -8%	+10% to 15%	+7% to 17%	-3% to +7%	0% to +10%	-10% to 0%	+18% to +28%

Table 5-8: Likely differentials per KPI in 2030 between the four market entry scenarios and the baseline [Source: Axon]. ***Note: These differentials assume that all scenarios are feasible from an operational perspective (e.g., it is feasible to deploy the necessary access networks as and when needed).***

As for the baseline estimates, we describe below the rationale behind the hypotheses considered for each of these scenarios:

- **ARPU**. The expected evolution under scenarios 1 and 2 has been built on the hypotheses discussed earlier in this section, as we consider these scenarios to be reasonably similar to the strategy followed by Yoigo in Spain, Free in France or Tele2 in the Netherlands. On the other hand, we believe that under scenarios 3 and 4 the 4th entrant would have a much more limited margin to act as a "disruptive" player and, therefore, we expect a lower reduction of ARPU as compared to the first two scenarios.

- **Subscribers**. Similar to our previous arguments with regards to ARPU, the expected impact on the number of subscribers has relied on the conclusions reached in the previous paragraphs, considering a likely higher impact for scenarios 1 and 2 (with a higher potential for the MNO to play a disruptive role) than for scenarios 3 and 4.

- **Network OpEx and Depreciation**. As for the hypotheses considered for the baseline scenarios, the expected evolution of these two indicators under each of the four potential market entry scenarios has been extracted from the Bottom-Up model carried out, which is described in Annex A.

- **Direct and retail costs**. We have considered that, the more intense the market competition, the higher the direct and retail costs operators would have to face to gain (or retain) market share. The assumptions are based on similar hypotheses considered by Axon in previous equivalent assignments.

- **G&A costs**. Further, we would expect that the fiercer the competition, the higher the efforts of the MNOs in cutting overheads and thus reducing their G&A expenses. As for the two categories above, the expected reduction of G&A costs compared to the baseline has been based on similar hypotheses considered by Axon in previous equivalent assignments.

Considering the historical information presented in Table 5-5 and the assumptions laid out in Table 5-7 and Table 5-8, we have assessed the likely long-term impact that a 4th MNO could generate on the market's revenues, costs and profits, as compared to our baseline. The results achieved are presented below:

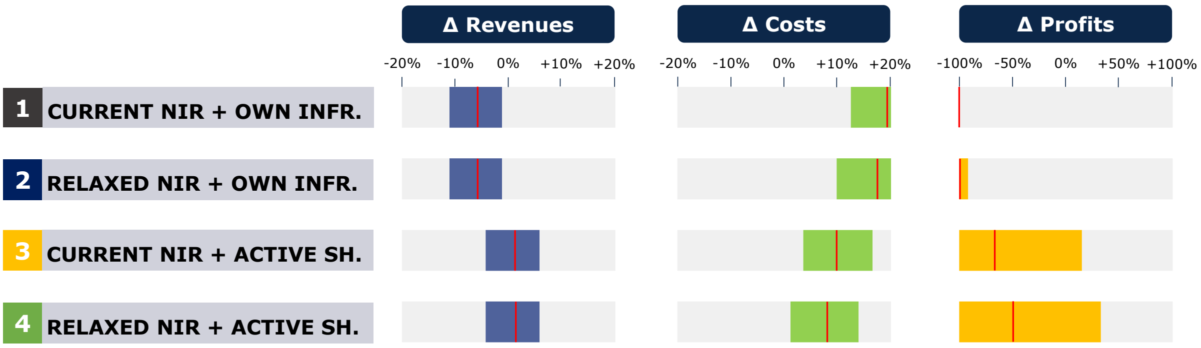

Table 5-9: Expected impact on revenues, costs and profits of a 4th MNO compared to the baseline [Source: Axon]. ***Note: The bars reflect the impact range to be expected under each scenario for each variable. The red lines reflect the average expected impact.***

The table below provides an alternative view to the above impacts if the operating profit of Proximus (in the range of 10-15%) is taken as a reference for the market:

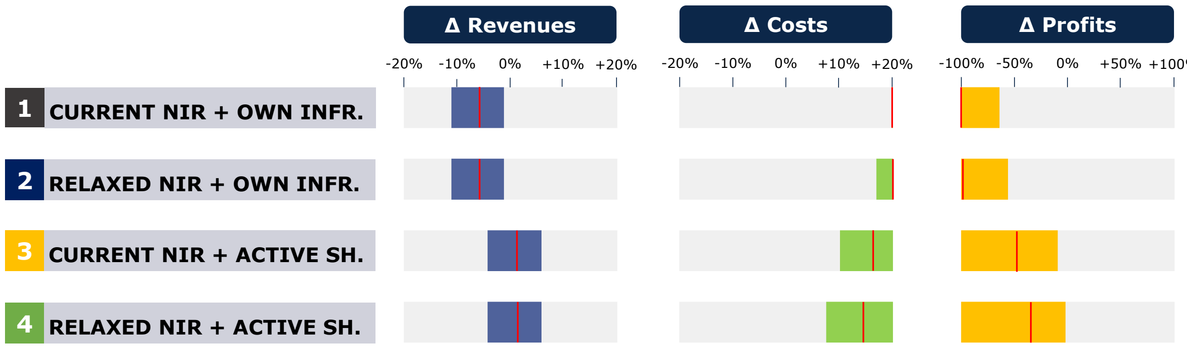

Table 5-10: Expected impact on revenues, costs and profits of a 4th MNO compared to the baseline, considering Proximus' operating profit as a reference [Source: Axon]. ***Note: The bars reflect the impact range to be expected under each scenario for each variable. The red lines reflect the average expected impact.***

As these two tables show, the market entry scenarios considered are expected to have a mixed effect on revenues and a certain increase in costs, rendering the entry of a fourth MNO a difficult mission in the light of the current profit levels enjoyed by the Belgian MNOs. Further insights that may be extracted from this analysis can be summarized as follows:

- Even if NIR limits are relaxed, the deployment of a new radio access network in the country seems impractical from a financial perspective. Such a strategy would lead to an increase in total market costs of at least 10% which, even if revenues remain flat, would be unbearable under the current operating profit margins.

- The current regulatory regime adopted in the Flemish and Walloon regions in terms of NIR limits does not "penalize" the deployment of a new mobile access network because the relevant limits are defined separately for each operator. Consequently, given that around 90% of the existing sites are located in these areas, we do not expect that a reduction of the NIR limits would significantly contribute to enhancing the financial outlook of a potential 4th entrant.

Based on these findings, we identify below the following three basic long-term possibilities for the Belgian mobile market (without excluding possible commercial/technical variations of these three basic scenarios):

1. A 4th MNO enters the market by deploying its own network. Even if it tries to enter into a price war in the early years, potentially bringing the overall market to losses for a few years, in the long term we could expect prices to go up to sustain profitability or two MNOs looking at a merger to improve efficiency and economies of scale. All other things being equal, we do not consider any of these likely long-term outcomes beneficial for the Belgian telecoms market and its citizens.

2. A 4th MNO enters the market under a RAN sharing agreement with an existing MNO. While we do not expect this new MNO to deploy significant or any assets in the access network – it would basically pay traffic-based fees to its partner, as if it were an MVNO – it would own its transmission and core networks. We are of the opinion that this business case would be financially appealing mostly to an existing telecoms operator. Under this scenario, the following financial impacts would be expected in the market:

    a. Revenues: Uncertain long-term impact compared to the baseline.
    b. Costs: Likely increase of 5-15% in the long term, mainly driven by lower levels of efficiency in network operation (e.g., spectrum would be divided across 4 MNOs instead of 3, given that no spectrum sharing is allowed to date, driving the overall number of sites to be deployed in the market higher).
    c. Profits: As long as the new entrant is an existing operator in the broader Belgian telecoms market, we believe it would be possible for this new entrant and the market as a whole to remain profitable in the long term, even if they had to "cross the desert" for a few years. Even so, we would expect overall market profits to decline by 30-60%.

3. Unless the 4th MNO involves the participation of an existing player in the Belgian telecoms market, we find little benefit in such an entity to enter the market as a RAN-sharing MNO rather than as an MVNO (or a national roaming-based entity). Therefore, if no existing telecoms player in Belgium is interested in becoming an MNO, we believe the entry strategy with the best risk/reward ratio for a new entity interested in participating in the Belgian mobile market, and for the mobile market overall, would be for it to enter as an MVNO. Given that different MVNOs already exist today in the Belgian market, our opinion is that this scenario would be unlikely to lead to any major impact in terms of revenues, costs and profits to the market.

Based on the three potential long-term outcomes projected above, we believe that it is only sensible to consider the second option as a reasonable entry strategy for a 4th MNO. Moreover, as the feasibility of the third of the scenarios previously presented (keeping the current NIR limits with the 4th MNO operating based on a RAN sharing agreement) is uncertain, scenario 4 (relaxed NIR limits + RAN sharing) will constitute the base case scenario for the new entrant that will be considered in the remainder of this section. Additionally, we note that, in order to make this strategy as compelling as possible for the market and the potential new entrant, it would be advisable for the BIPT and any other relevant authorities in Belgium to:

1. Allow spectrum sharing across MNOs, at least when these have reached RAN sharing agreements. Such a regulatory move will not only promote an efficient usage of such a scarce resource, but also reduce the impact on costs of a 4th MNO to the mobile industry in Belgium as a whole.

2. Relax the NIR limits, not only in Brussels but also in Flanders and Wallonia. As in the case above, this would allow a more efficient network deployment in this region, leaving room for cost optimization strategies to the MNOs, which may partially offset the extra costs the entry of a 4th MNO may generate in the market.

Therefore, in summary, we believe that the best business case for a fourth MNO in the Belgian mobile market would involve i) the conclusion of a RAN sharing agreement with an existing MNO and ii) participation of an existing player in the Belgian telecoms market who may benefit from its existing technical and operational infrastructure. Under this scenario, we believe that total market revenues could either grow or fall by around 5% by 2030, costs would likely increase by 5-15% in the long term, and mobile-related operating profits (for the sector as a whole) could decline by at least 40.

The expected outcome in terms of impact on costs and profits could likely be enhanced if the BIPT and/or the relevant regulatory authorities in Belgium allowed spectrum sharing across MNOs and relaxed the NIR limits, at least in the Brussels region.

Expected impact on competition, investment and employment

The entry of a 4th MNO is bound to affect the conditions of competition, and the most quantitative way to measure this effect traditionally relies on the HHI.[97] For the impact on investment, our sources of reference include the available literature, and examples of metrics from other countries (Spain and France). Finally, given the absence of any studies systematically focused on employment, our relevant impact assessment relies on the close correlation observed in the telecoms sector between employment and overall revenues.

Impact on competition

We provide below examples of the impact on HHI of recent market entries and/or mergers in Europe:

[97] See footnote 12, above.

Reference	Impact of a 4th entrant on HHI	Indications
Spain (2008)	↓ 12%	Based on market entry of a 4th MNO
France (2012)	↓ 26%	Based on market entry of a 4th MNO
Austria (2013)[98]	↓ 17%	Based on a 4 to 3 merger
Germany (2014)[98]	↓ 13%	Based on a 4 to 3 merger
Ireland (2014)[98]	↓ 12%	Based on a 4 to 3 merger
Average	↓ **16%**	

Table 5-11: Examples of the impact of a 4th entrant on HHI [Source: Axon and BEREC]

In the case of 4 to 3 mergers, the impact is measured as the difference in the HHI right before and after the merger, as this has an immediate implication on the competition levels in the market. On the other hand, in the case of new market entries, the impact is measured as the difference in HHI 3 years before and after the entry of a 4th MNO.

For both types of events, as expected, the case studies available point to a decrease in the HHI (i.e., an improvement of the competition levels in the market). In particular, HHI should be expected to decrease by around 10-20% three years after the entry of a 4th MNO.

In turn, a comprehensive study of the impact of HHI on retail prices performed by Axon, based on data from 45 countries from different geographies, suggests that HHI does have an impact on retail prices, as shown below:

98 BEREC (2018).

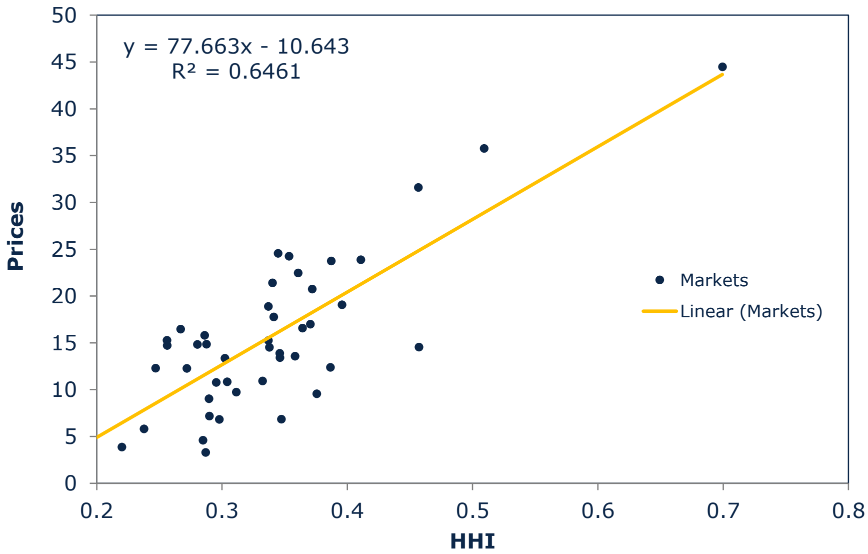

Figure 5-4: Relationship between HHI levels and retail prices [Source: Axon based on data from the GSMA intelligence database]. ***Note: Includes data from 45 countries from different geographies. Price levels are PPP-adjusted for the sake of comparability.***

In particular, according to this analysis, a reduction of the HHI by between 10 and 20% would lead to a reduction of retail prices by between 13% and 26%, which is notably aligned with the estimates on retail prices presented above in the "Preliminary thoughts on the impact on retail prices".

Any such impact on HHI is expected to be driven solely by the entry of a 4th MNO. Although, as mentioned above, our analysis in this Chapter is "agnostic" on the timing of a transition to 5G, it is worth noting that, in and by itself, the transition to 5G would be unlikely to affect the current HHI and market structure, at least as regards the telcos' "traditional" business.

Impact on investment

In terms of investment, it can be expected that, under the base case market entry scenario described above, total market investment could go up in the first years, mainly driven by:

- A lower efficiency market-wide in the deployment of access networks. Since the same spectrum would be distributed among four MNOs instead of three, each MNO would end up with lower spectrum than under the baseline scenario and would thus be required to deploy more sites.

- The need for the new entrant to deploy additional infrastructure to connect its existing assets with the radio-access sites it will now need to manage[99].

As a result, and depending on the regulatory framework in place at the time of entry and the existing infrastructure of the new entrant, we believe that a 4th MNO could have a positive short-term impact on investment, of up to 500 million EUR. Nevertheless, the actual impact could be well below this estimate.

In the long term, however, the initial network-related investments coming from the market entry of a 4th MNO are likely to fade out. The table below provides a summary of the relationships found between market structure and long-term investment in the telecoms sector in different relevant reports/studies published to date:

Reference	Impact of a 4th entrant on investment	Indications
Houngbonon and Jeanjean (2014)	Inverted U relationship between competition and investment	Observations from 77 countries from 2003 to 2012
Frontier Economics (2015)	No significant effect on total investment	Based on an analysis of 4 to 3 mergers
WIK (2015)	No significant effect on total investment	Based on an analysis of 4 to 3 and 5 to 4 mergers
Lear et al. (2017)	Potential positive effect, although vanished when the data series are smoothed or when measured on a per subscriber basis.	UK 5 to 4 merger in 2010
Genakos et al. (2018)	Lower investment per operator, no significant effect on total investment	Post-merger analysis from 4 to 3 MNOs.
Wellmann (2019)	Lower investments traded-off with lower price levels	Study on competition for 48 MNO from 14 European countries between 2011 and 2016
Abate et al. (2020)	Greater investment in more concentrated markets	Analysis on 29 European countries between 2011 and 2018
Berne et al. (2019)	Inconclusive	Entry of Free in the French market

Table 5-12: Average impact of a 4th entrant on investment [Source: Axon based on publicly available reports]

[99] Note that no investment in radio-access sites by the new entrant is considered to be necessary under the base case market entry scenario, as it will solely rely on the sites of the existing MNO.

On top of these references, we include below an overview of the evolution of the CAPEX/revenue ratio in Spain and France, before and after the entry of a 4th MNO, at market and operator level:

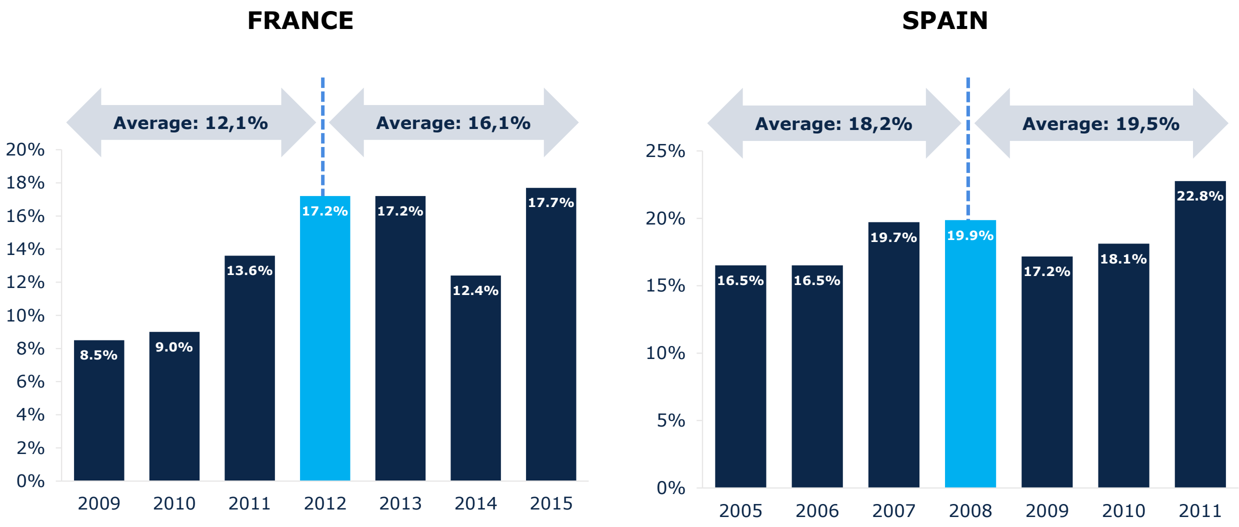

Figure 5.1: Evolution of the CAPEX/investment ratio in France and Spain before and after the entry of a 4th MNO [Source: Axon based on data reported by the CNMC and ARCEP]

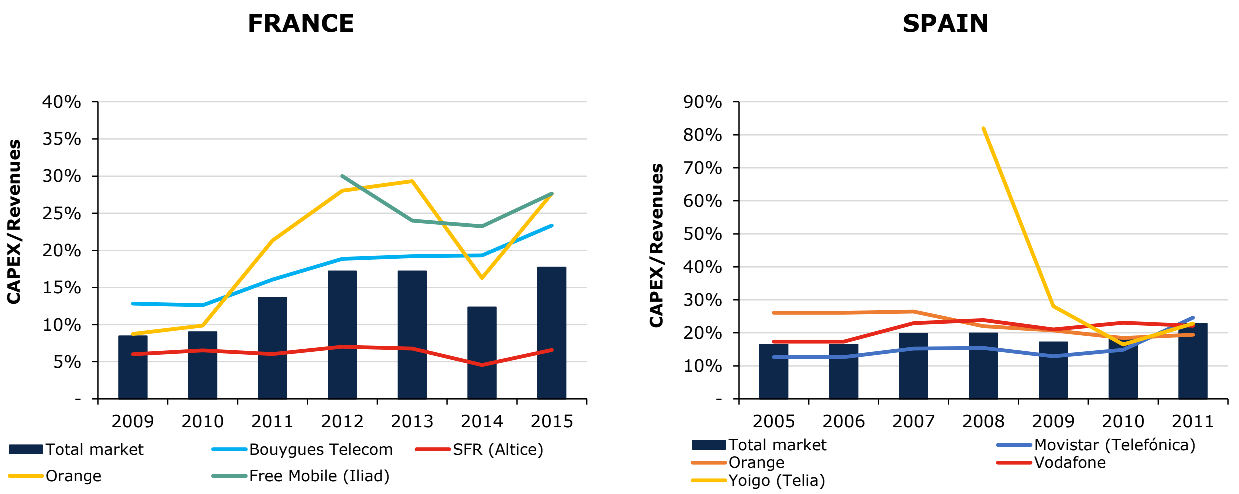

Figure 5-5: Evolution of the CAPEX/investment ratio in France and Spain before and after the entry of a 4th MNO, at operator level [Source: Axon based on data reported by the CNMC and ARCEP]

While it could be argued that the entry of a 4th MNO did have a positive impact on investment in France, it is important to acknowledge that this behaviour was primarily driven by the expansion of the existing 3G networks at the time of the new market entry (e.g., in 2013, Bouygues and Free upgraded their 3G networks with the HSPA+ technology) and the initial roll-out of 4G networks. When assessed at operator level, while it could also be argued that the entry of a 4th MNO pushed some MNOs (such as Movistar in Spain) to invest more heavily, it is complicated if not impossible to draw a clear link between the two.

Actually, this observation is aligned with the outcomes of several reports pointing out to the unique behaviour of the telecoms market as compared to other industries, with frequent and important technological changes, together with CapEx-intensive spectrum auctions that blur any potential impact that market structure may have on the overall sector's investment in the long term. As a result, it may be argued that, in and by itself the entry of a 4th MNO is unlikely to generate any relevant long-term impact on market-wide investment.

Impact on employment

There are few published reports/studies assessing the impact of a 4th entrant on employment. Moreover, the few reports that exist usually focus on the implications of market structure on employment, from the perspective of 4 to 3 mergers. However, in this case, the insights from the results of 4 to 3 mergers (typically, job cuts) cannot be directly extrapolated to the assessment of the likely impact of a new entrant on employment.

Consequently, given the lack of relevant public reports quantifying the likely impact on employment of a 4th MNO, we have assessed its implications under the perspective also adopted to evaluate the potential impact on prices. Specifically, the figure below illustrates the evolution of employment in the telecoms sector before and after the entry of a 4th MNO in Spain (left) and France (right):

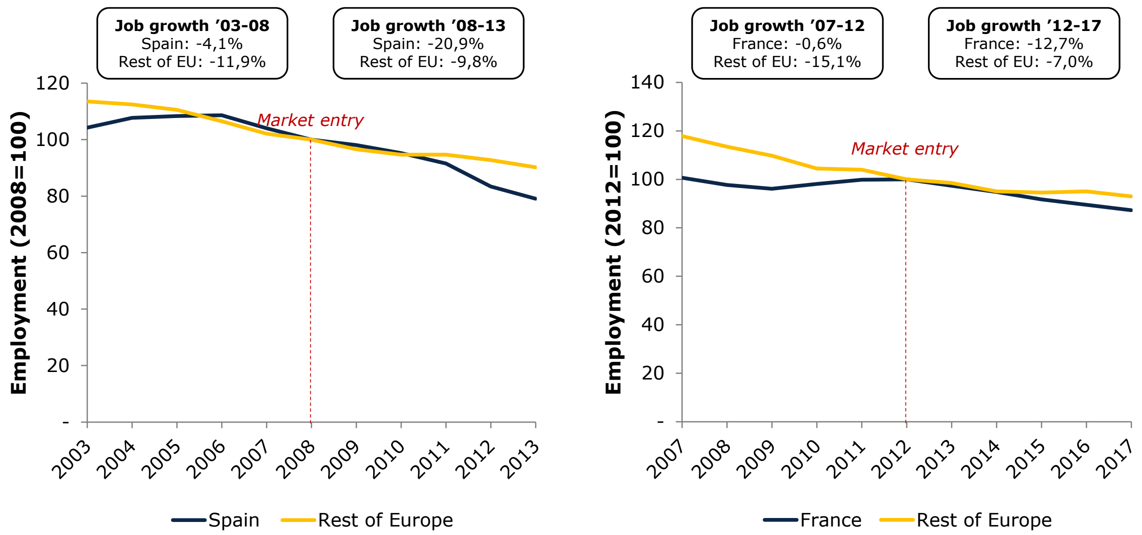

Figure 5-6: Evolution of employment in the telecoms sector before and after the entry of a 4th MNO in France and Spain [Source: Axon based on data from the ITU's WTI Database 2020]. ***Note: The analysis is not presented for the Netherlands as data on employment for this country is incomplete in the ITU's WTI Database.***

The two case studies above strongly suggest that, contrary to likely expectations, the entry of a 4th MNO has led to the destruction of ~20% of related jobs in five years. In particular, we identified that, in both countries, the evolution of the number of full-time equivalent employees has been highly correlated to the revenues of the sector from the year 2000 until 2019, as shown below:

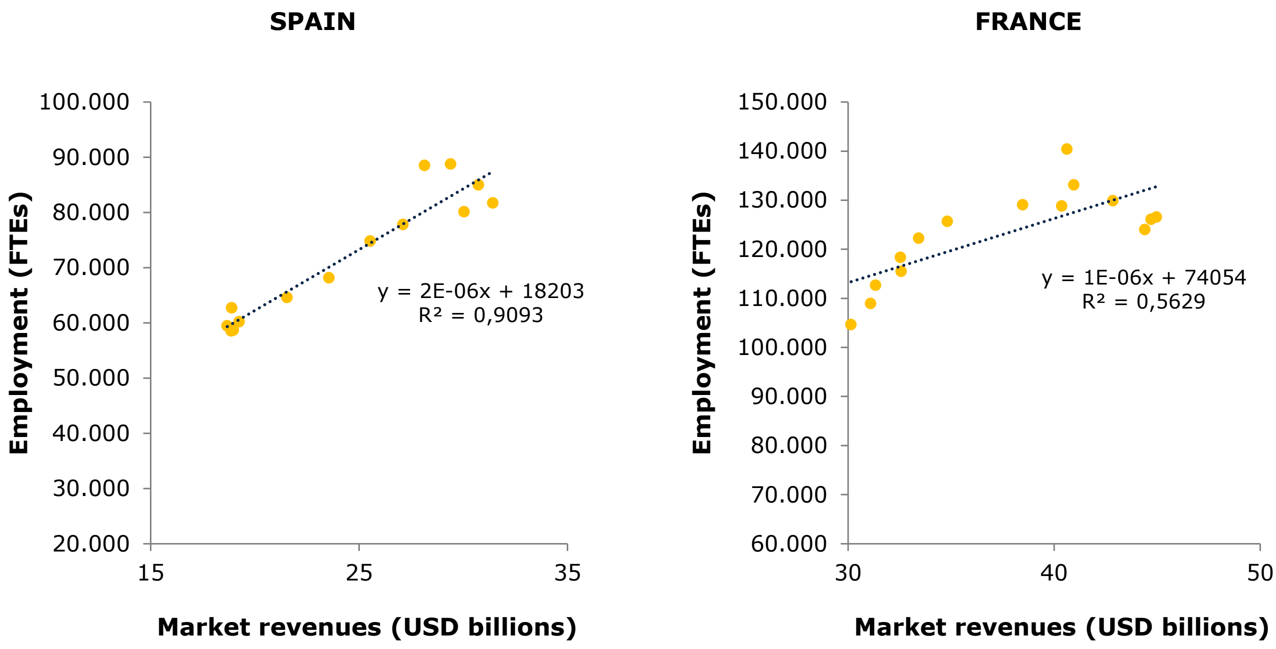

Figure 5.2: Relationship between revenues and employment in France and Spain from 2000 until 2019 [Source: Axon based on data from the ITU's WTI Database 2020]

References from France and Spain, although limited in number, suggest that every 1% of a decline in market revenues leads to a 1% decline in employment. Given the uncertain impact of a 4th MNO on the evolution of market revenues in the long term, the impact of the 4th MNO is equally uncertain in terms of employment.

However, assuming a potential impact of ±5% on market revenues and considering that the Belgian telecoms market employed 17.387 persons in 2019, with ~3.800[100] of them related to the mobile operations, this yields a potential impact of ~±200 jobs. It may be thus concluded that, in and by itself, the presence or absence of a 4th market entrant is unlikely to drive job generation/destruction figures in the country.

[100] Axon's estimate based on the ratio between mobile-related employees and total telecoms employees in Belgium in 2008 (last year for which this split is available in the ITU WTI's database).

Expected impact on consumers

A new entrant will most likely have no choice but to differentiate its retail tariffs, in order to gain share in Belgium's telecom market. As discussed in previous paragraphs, this is likely to generate a consumer surplus, through the combination of two effects:

- A reduction in the prices Belgium's citizens pay already for mobile electronic communications services; and
- A growth in the number of connections as a result of such price reduction.

Assuming an aggressive price-war, our estimates indicate that a new entrant, capable of leveraging economies of scale from its already-existing operations (e.g., in the fixed market) could generate a long-term reduction of up to 13% on the retail prices, accompanied by an increase in the number of active connections by around 10%.

Overall, we expect that the entry of a 4th MNO in the market could add to the **annual consumer surplus by up to 350 million EUR** in 2030[101].

Concluding remarks

To sum up our findings of a 4th MNO's impact on the Belgian ("traditional") telecoms sector:

- We believe that a 4th MNO entry in Belgium will be financially appealing mostly to an entrant with a RAN sharing agreement with an existing MNO, and a background as an existing player in the broader Belgian telecoms market, with some existing own technical and operational infrastructure. Under this scenario, total market revenues could either grow of fall by around 5% by 2030, costs would increase by 5-15% and mobile-related operating profits would likely plunge by at least 40%[102], although the result could be better if spectrum sharing is allowed and the present NIR limits are relaxed.
- Overall investments are unlikely to be affected significantly by the presence or absence of a 4th market entrant, either in the short term (if the 4th MNO obtains a RAN sharing agreement) or in the long term (under any scenario).

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[101] Calculated as the differential in the end-users' annual expenditure in mobile telecoms services by 2030, with and without a 4th MNO. It takes into account the lower prices consumers would be expected to pay with the entry of a 4th MNO as well as the higher number of active connections in that scenario.

[102] The impact on profits at operator level may vary significantly. While the strongest may be well capable of resisting such a 40% decrease (and even, at least partially, compensate it through new use cases that 5G may enable), others may be brought into losses as a result of the 4th MNO entry.

- Depending on the potential impact of the 4th MNO on total market revenues, its entry could lead to the generation (if revenues increase) or destruction (if revenues fall) of around 200 jobs in the telecoms sector.

- The entry of a 4th MNO in the market could add to the annual consumer surplus by up to 350 million EUR in 2030.

5.2.2. **Impact on society**

Besides the direct implications for the telecoms sector discussed in the previous section, the entry of a 4th MNO into the Belgian mobile market may also have a noticeable effect in other sectors of the national economy.

Such indirect impact is typically assessed through the input-output tables generated by national governmental entities. These tables, and more specifically, the multipliers they contain are a standard application of Leontief's traditional input-output model. They measure the response of an economy to an exogenous shock and allow us to estimate the effect of changes in final demand components (change in government expenditure, investment, exports, etc.) on industry-level output, employment or income.

The latest available version of the inputs-outputs tables in Belgium was published by the Federal Planning Bureau in 2019 and refers to the year 2015.[103]

Based on these tables, and considering that a 4th entrant could imply an increase/reduction of ±5% on the telco sector's revenues, we have assessed below the indirect impact of the 4th entrant on production (output) and employment in Belgium:

- **Production**: Assuming a potential increase/reduction of ±125 million EUR in revenues in Belgian telecommunications, and considering the output multiplier of 1,39 for the telecommunications services sector, this reduction is expected to lead to an additional ±50 million EUR in national output (i.e., total projected impact of ±175 million EUR to the total national output by 2030). This figure is insignificant compared to the expected positive economic impact of 5G.

- **Employment**: Taking the same potential increase/reduction on revenues as a reference and considering the 3.91 simple employment multiplier for the telecommunications sector in the tables provided by the Federal Planning Bureau, we estimate that a new mobile entrant could lead to the generation/disappearance of

103 Available here: https://www.plan.be/databases/data-66-en-input_output_tables_multipliers_2015

490 jobs (directly and indirectly). Further, considering the 1.82 Type I employment multiplier reported in the Input-Output multiplier database, we may conclude that:

- Up to around 270 jobs could appear/disappear in the telecommunications sector, a very similar conclusion to that reached in the previous section. The sign of the impact (upwards or downwards) will depend on the eventual impact of the 4th MNO on the mobile sector's revenues (a ±5% is expected).
- Up to around 220 jobs could appear/disappear in other sectors.

5.3. Environmental impact

This section presents the impact of the market entry of a new mobile network operator in Belgium from four different perspectives:

- Impact on electromagnetic radiation
- Impact on power consumption
- Impact on e-waste
- Impact on GHG emissions
- Visual, noise and air pollution impact

The subsections below quantify the expected impact of 5G on each of these verticals.

5.3.1. Impact on electromagnetic radiation

As presented in Subsection 3.1.4, the regulations in place limiting the electromagnetic radiation coming from mobile installations in the different Regions of Belgium may play a relevant role in the entry of a new MNO in the market.

- **Brussels Region**. The relevant rules define a specific cumulative threshold, and each antenna of each operator may not exceed 33% of that threshold. In our view, with the entry of a new operator, this limit should be adjusted, and two directions may be followed:
  - Maintaining the cumulative limit and reducing the individual limit to 25%. This change would affect all operators, further constraining their operations, which would likely lead to degraded quality of service and/or the need for additional infrastructure to comply with the existing limits, but it would not lead to increased non-ionising electromagnetic radiations in the region.

- Increasing the cumulative limit, so that the operators have the same individual limit. This approach would leave the existing operators unaffected, but would lead to a 33% increase in electromagnetic power emissions (to a total of 0,128 W/m^2), which would, however, still leave the limits in place in Brussels 97% below the limits set out by the ICNIRP.

Therefore, depending on the regulatory approach adopted, non-ionising radiations in the Brussels Region may either be unaffected or increase by 33% (while still 97% below the limits recommended by the ICNIRP and the EC).

- **Flemish Region:** In this Region, the existing regulation sets two main limits: i) a cumulative limit (similar to the one set in the Brussels region, albeit more relaxed) and ii) a limit which is measured on a per frequency band, per technology and per operator basis. In practice, the latter limit is always the most restrictive for mobile operators. This limit would remain the most restrictive in the event of the entry of a new operator in the market. For this reason, we consider that the new entrant will not be particularly affected by the regulation in the Flemish Region.

  Under the current regulation in the Flemish region, while still compliant with the limits set, the entry of a new operator could lead to an increase of 33% in the power of the electromagnetic radiations received by the citizens.[104] However, in practice, this would result in an approximate emitted power density of 0,57 W/m^2 [105], still ~87% below the limits defined by the ICNIRP.

  The market entry of a 4th MNO would also lead to an increase of electromagnetic radiations by 33% if the recent proposal to update the NIR limits from the Flemish Region is taken forward, although in this case the impact in absolute numbers would be from 0,64 W/m^2 to 0,86 W/m^2. Under this scenario, the electromagnetic radiations would lie 81% below the limits recommended by the ICNIRP and the EC.

- **Walloon Region:** In this Region, the regulations define a limit measured on a per technology and operator basis. As in the Flemish Region, this type of regulation does not represent a relevant issue for the entry of a new operator, as it would fall under a separate limit.

  Similarly as in the Flemish Region, under the current regulation in the Walloon Region, while still compliant with the limits set, the entry of a new operator could

[104] On top of the effect of the deployment of 5G networks.

[105] Considering 6 antennas for each operator (i.e., without deployment of 5G networks).

lead to an increase of 33% in the power of the electromagnetic radiations received by the citizens. However, in practice, this would result in an approximate emitted electric field of 0,29 W/m^2 [106], still ~94% below the limits defined by the ICNIRP[107].

We can therefore conclude that the impact in terms of electromagnetic radiation will be different in each Region.

1. In Brussels, if the existing limits are split among MNOs, electromagnetic radiation would be maintained, at the expense of additional costs for operators and a degraded quality of service. If, on the other hand, the regulation slightly increases the current thresholds, the existing operators would be unaffected by the new market entry, while electromagnetic radiation would increase but still be 97% below the limits defined by the ICNIRP and the EC.

2. In the Flemish and Walloon Regions, we do not expect that the existing regulations limit the development of a new entrant. However, we may see slight increments in the electromagnetic radiation, which nonetheless would still be quite below the limits defined by the ICNIRP[108].

5.3.2. **Impact on power consumption**

Impact from the network

According to the outcomes of the Bottom-Up cost model developed, the inefficiencies driven by a 4th mobile network operator in the deployment of mobile radio access networks are expected to lead to a potential increase of approximately 15% of sites in the long term – as compared to a baseline with only three MNOs.

Considering that the radio access network contributes to around 85% of the total energy consumed in telco networks, this would likely lead to a 13% in energy consumption.

On the other hand, we believe that the entry of an additional service provider could also increase energy consumption in terms of:

- Additional transmission elements: Even if the transmission equipment of each operator handles less traffic, the deployment of an additional transmission network

[106] Considering 3 antennas (2G, 3G and 4G) for each operator (i.e., without deployment of 5G networks).

[107] Considering the ICNIRP thresholds at 900 MHz. The gap between the emissions and the ICNIRP limit would be greater if measured in higher frequency bands.

[108] Considering an overall limit of 0,76 W/m^2 for Flanders and 0,39 W/m^2 for Wallonia when 5G is deployed.

would increase power consumption. In our view, this aspect could increase overall power consumption by around 1%. This aspect could be avoided through the use of regulated leased line products, reusing existing infrastructure, even if this will ultimately depend on the strategy adopted by the new entrant.

- Duplicated core network and data centres: the new operator would need to operate its own core network and platforms, introducing further inefficiencies. According to Proximus, their data centres represented 14% of their total energy expenditure in 2020[109], so the presence of a new entrant may result in an additional increase in power expenditure of between 2-3%. This increase could be minimised if the new entrant is an existing player in the Belgian telecoms market, with existing core infrastructure and data centres already in place.

In summary, the entry of a new operator may bring some inefficiencies to energy consumption in Belgium. However, we consider these would be relatively minor and could moreover be partly avoided. All in all, we expect that the entry of a new operator could result in an increase in the telco network energy consumption in Belgium of around 15%.

Impact from the users

In terms of impact on the power consumed by mobile users, while it is true that it is expected that a new entrant could increase the number of subscribers, it is uncertain whether the new subscriptions would require use of new/additional end-user devices.

If, as outlined in section 5.2.1, the number of subscriptions was to increase by up to 15% as a result of the entry of a 4th MNO, it is then possible to conclude that at most, the energy consumption increase from the users' perspective is not going to exceed that 15%.

5.3.3. **Impact on e-waste**

In line with the considerations presented in subsection 4.2.3, a 4th MNO operating through a RAN sharing agreement could basically add to the e-waste generation through additional SIM cards of user devices. However, as indicated in that section, compared to the total e-waste annually generated in Belgium, e-waste generation from these elements is negligible (i.e., only about 0.25% of the total), and any additional e-waste through a 4th MNO entry would represent, at most, a modest increase of this small percentage.

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109 Reference: Annual reports | Proximus Group

Therefore, we conclude that, even though a 4th MNO could contribute to an increase in the number of SIM cards (e.g., through increase requests for mobile number portability) and smartphones (e.g., by offering free smartphones together with their post-paid packages), any such impact would be negligible: a minor increase over the existing 0.25% of total e-waste generation in Belgium, thus representing well below 0.25% of the total.

5.3.4. **Impact on GHG emissions**

In a worst-case scenario, whereby a new entrant would not utilise any renewable energy, and assuming an optimistic market share of 20% by 2030, we can draw an estimate on the worst-case impact of the new entrant on Belgium's GHG emissions.

Accordingly, taking as a reference the total potential emissions of Telenet in 2019 (42,92 K metric tons of CO2 equivalent)[110] and its market share of 26,89% in 2019, we may conclude that, all other things being equal, the new entrant could generate up to 31,93 K metric tons of CO2 equivalent. This would represent only a 0.03%[111] increase in total GHG emissions in Belgium. Moreover, this is based on the worst-case scenario, assuming no use of any renewable energy sources by the 4th MNO.

5.3.5. **Visual, noise and air pollution impact**

According to the estimates of the Bottom-Up model implemented, the number of sites in Belgium is expected to increase by up to 15% if a 4th MNO enters the mobile market, even if it does so under a RAN sharing agreement. This increase, coming from an extra network deployment by the existing MNOs, would be driven by a less efficient distribution of spectrum across the market players, as the same spectrum will need to be shared among four players instead of three.

Therefore, while the conclusions reached in Subsection 4.2.5 , especially in terms of the deployment of radio access cells, could be worsened by 15%, the conclusion remains the same: the deployment of 5G in combination with the entry of a 4th MNO will have a very limited visual/aesthetic, noise or air pollution impact on the environment.

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110 Based on location-based criteria that do not take into account the use of renewables. Reference: Telenet Sustainability Report 2019.

111 Basis for calculation total CO2 equivalent emissions in Belgium. 118.522.00 (ton/year). Reference: United Nations, climate change unit.

5.4. Conclusion

Our conclusions on the operational feasibility and implications of a new entrant in Belgium can be summed up as follows:

- A 4th MNO entry in Belgium will be viable under certain conditions, and the most appealing (financially) scenario, with possible variants, would involve a RAN sharing agreement with an existing MNO, combined with the new entrant's ability to rely on own existing technical and operational infrastructure. Under this scenario, total market revenues could either grow or fall by around 5% by 2030, costs would increase by 5-15% and mobile-related operating profits would likely decline by at least 40%[112], although the result could be better if spectrum sharing is allowed and the present NIR limits are relaxed.

- Total new investments are unlikely to be affected either way by the presence of a 4th MNO. Its entry could lead to the generation/disappearance of up to 270 jobs in the telecoms sector.

- The entry of a 4th MNO in the market could add to the annual consumer surplus by up to 350 million EUR in 2030.

- Impact on electromagnetic radiation will vary by Region. In Brussels, if the existing limits are split among MNOs, electromagnetic radiation would be maintained, at the expense of additional costs for operators and a degraded quality of service. If, on the other hand, the regulation slightly increases the current thresholds, the existing operators would be unaffected by the new market entry, while electromagnetic radiation would increase but still be 97% below the limits defined by the ICNIRP and the EC. In Flanders and Wallonia, the entry of a 4th MNO would likely raise electromagnetic radiation levels by 33% (to a total of 0,57 W/m^2[113] in Flanders and 0,29 W/m^2 in Wallonia), while these would be still quite below the limits defined by the ICNIRP by ~ 87%[114] in Flanders and ~ 94% in Wallonia[115].

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[112] The impact on profits at operator level may vary significantly. While the strongest may be well capable of resisting such a 40% decrease (and even, at least partially, compensate it through new use cases that 5G may enable), others may be brought into losses as a result of the 4th MNO entry.

[113] 0,86 W/m^2 if the recent proposal to update the NIR limits from the Flemish Region is taken forward.

[114] 81% if the recent proposal to update the NIR limits from the Flemish Region is taken forward.

[115] Considering the ICNIRP thresholds at 900 MHz. The gap between the emissions and the ICNIRP's suggested limit would be broader if measured in higher frequency bands.

- The entry of a 4th MNO could result in an increase of power consumption by up to 15%.
- Impact on e-waste should be negligible (lower than 0.25% of the total e-waste in Belgium), at least as regards SIM cards or user devices.
- The entry of a 4th MNO should have a negligible visual/aesthetic, noise, air pollution impact on the environment, i.e., not exceeding the common impact of public works, and on GHG emissions (potential increase of less than 0.03% of the total GHG emissions in Belgium)

Annex A. Description of the cost model adopted to assess network-related impacts

To understand the network implications of the deployment of 5G networks (Section 4) and the market entry of a new mobile network operator in Belgium (Section 5), we have developed a bottom-up cost model, described, at a high level, in this Annex.

The model is rooted in the bottom-up cost model developed by the European Commission to calculate the cost of mobile services in all EU/EEA Member States, which has also involved input from Belgium. Given that the purpose of the present study goes beyond the objectives for the European Commission model, the model has been adjusted to calculate additional parameters for each mobile operator in Belgium (i.e., Proximus, Orange, Telenet, and, eventually, a fourth MNO) required to draw the conclusions presented in the study's above sections. These adjustments include, for instance, updates to a number of key inputs and the development of a module to dimension the 5G radio access network.

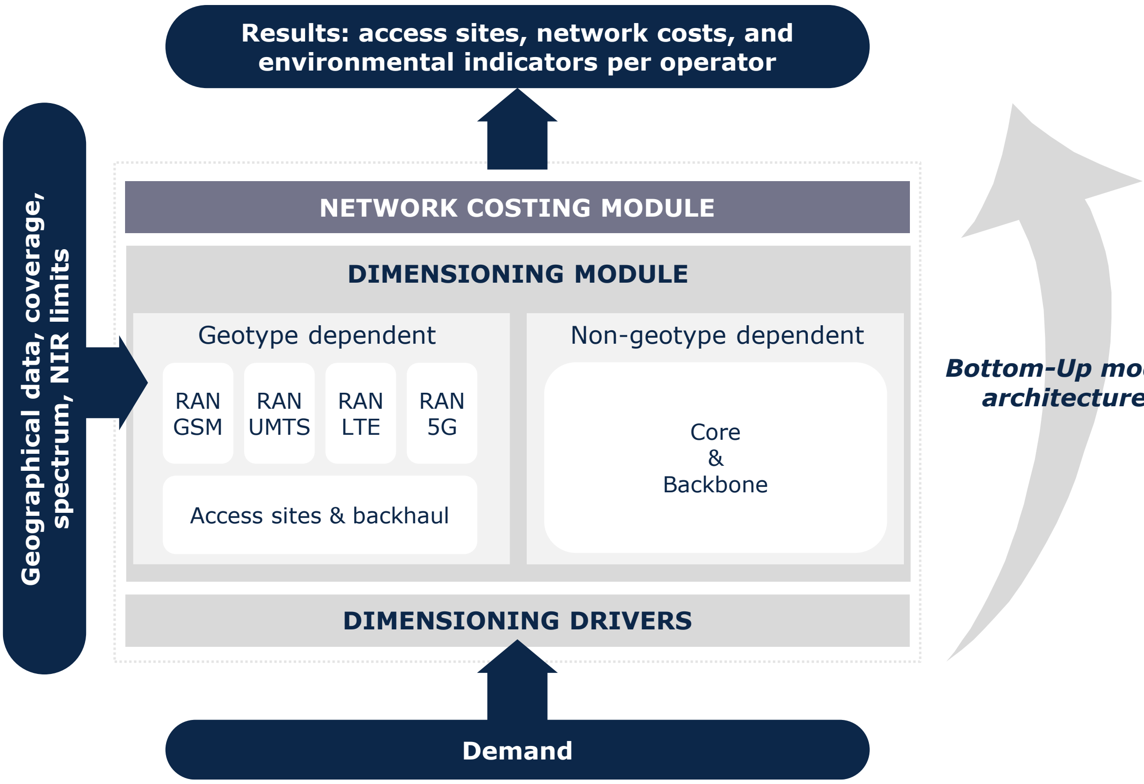

Figure A.1: Bottom-Up model architecture [Source: Axon]

Along with the structural changes required in the development of this model, some of the key inputs of the cost model have been updated and tailored for the Belgian market. The figure below presents the main inputs that have been updated in this model, along with the source for the new figures:

Figure A.2: Sources of information of the key inputs of the model [Source: Axon]

The following paragraphs provide a brief description of each of the key inputs presented above:

- **Demand**. The new model includes two main updates to the demand inputs:
  - **Extended demand forecasts:** Demand forecasts for all services have been extended from the year 2026 to the year 2031. This adjustment has been carried out by extrapolating the year-over-year growth rate in 2025. Considering its relevance for 4G and 5G networks, the image below presents the evolution of mobile broadband consumption included in the cost model:

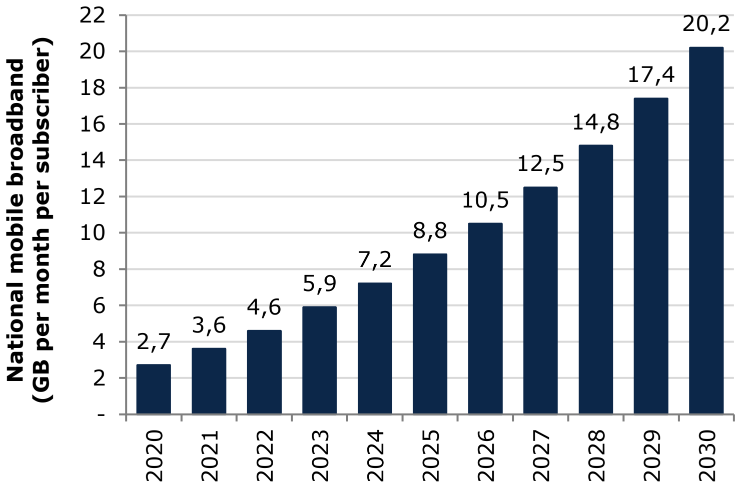

Figure A.3: Monthly data traffic per subscriber [Source: Axon]

- **Updated number of subscribers:** The number of yearly mobile subscriptions has been updated based on the latest figures available to the BIPT.

- **Coverage**: Parametrisation for 5G coverage has been introduced in the model. This input has been defined separately for the existing operators and for the new entrant, as coverage rates may not be the same along the years, especially in the initial years of the new entrant.

  - In the case of existing operators, 5G coverage rates are estimated considering the coverage obligations mandated by the BIPT (i.e., reaching 70% and 99.5% of population coverage after 3 and 6 years since deployment).

  - In the case of a new entrant, coverage rates for 5G are based on the potential obligations mandated by the BIPT (i.e., reaching 30%, 70%, and 99.5% of population coverage after 3, 6 and 9 years since deployment). Furthermore, as presented in Section 5, the model considers that the new entrant would operate only a 4G and 5G access network, and that the coverage of both access networks would follow equivalent rates of deployment.

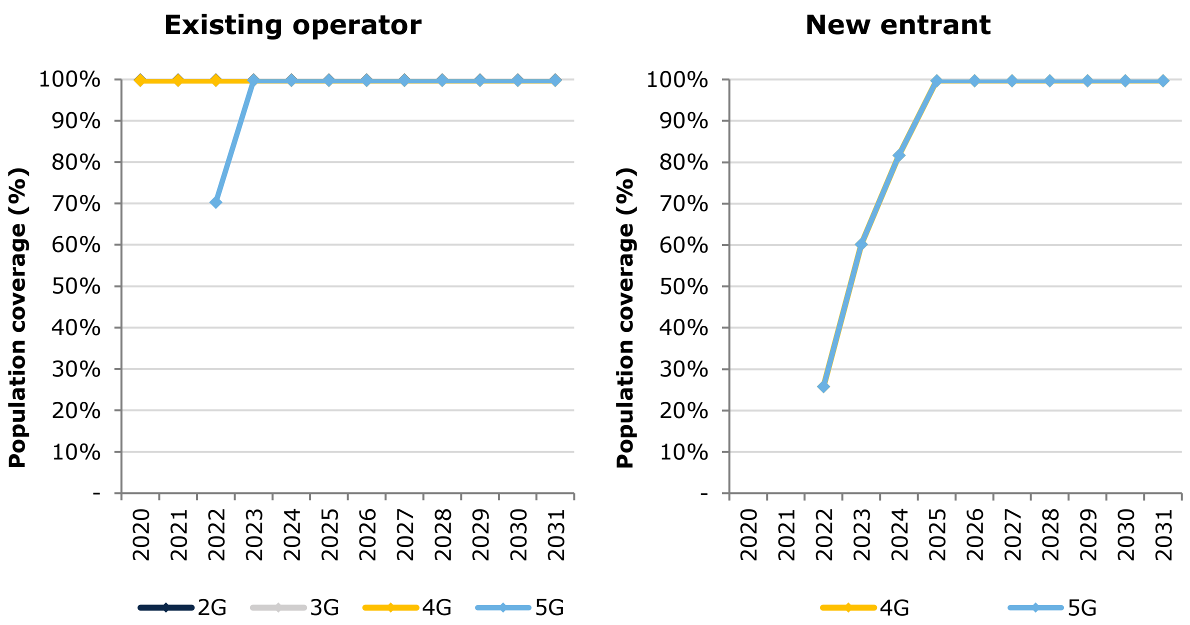

Figure A.4: Population coverage for the whole modelled period [Source: Axon]

Further details about the potential obligations for MNOs in the context of the deployment of 5G networks are provided in Section 4.

- **Spectrum**: Differently from the EC model, spectrum inputs in the new model are introduced separately for each of the modelled operators, based on the current spectrum holdings and the expected spectrum to be awarded to operators in the upcoming auction. As explained in Section 5, in the event that a fourth operator entries the mobile market, the spectrum inputs of the existing operators are adjusted to ensure the availability of spectrum for the new entrant. The exhibit below presents the spectrum holdings of the MNOs considered in the cost model with and without the new entrant.

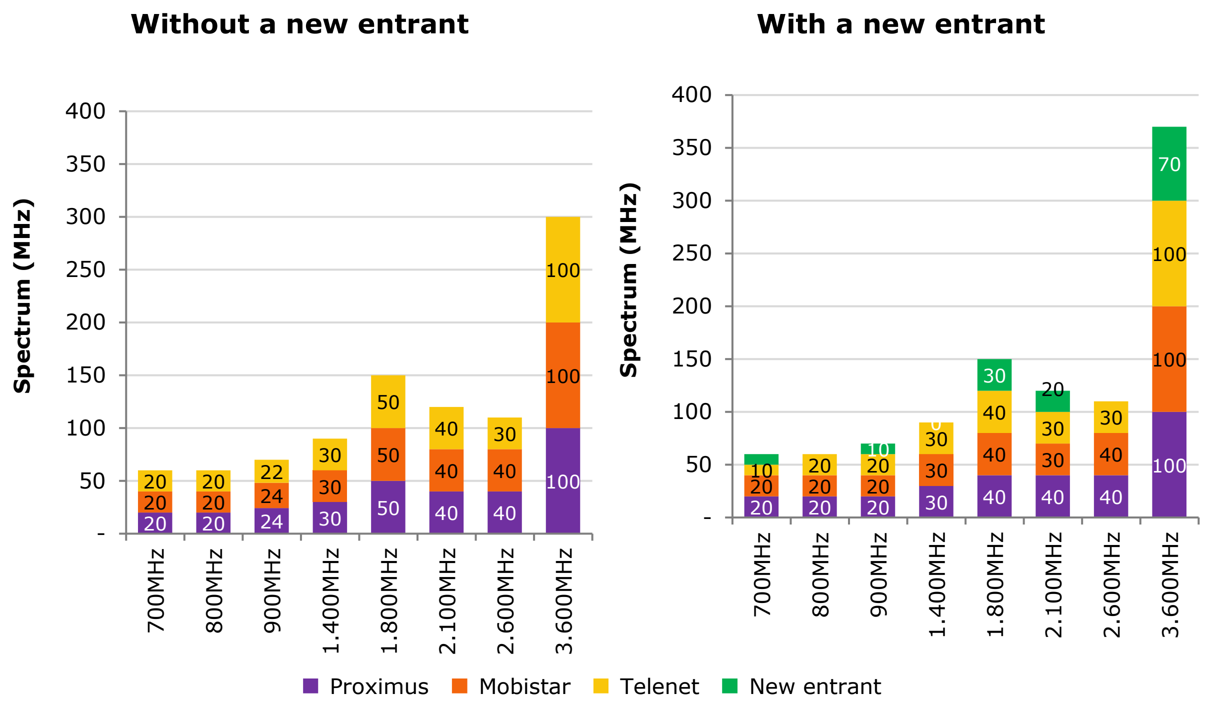

Figure A.5: Expected spectrum holdings of operators for the year 2022 [Source: Axon] ***Note: Figures represent spectrum in the uplink and downlink***

Furthermore, the model assigns each spectrum band to one or more access technologies. The table below presents the relationship between spectrum bands and access technologies:

Spectrum band	2G	3G	4G	5G	Comments
700 MHz				✓	
800 MHz			✓		
900 MHz	✓	✓	✓[116]	✓[117]	▶ In the case of the existing operators, a 2x5 MHz block is assigned to 3G and the remaining to 2G. ▶ For the new entrant, this band is split between 4G and 5G networks, due to the lack of low-band spectrum.

[116] Only for the new entrant

[117] Only for the new entrant

Spectrum band	2G	3G	4G	5G	Comments
1,400 MHz				✓	
1,800 MHz	✓		✓		A 2x5 MHz block is assigned to 2G and the remaining to 4G
2,100 MHz		✓		✓[118]	A 2x5 MHz block is assigned to 5G in the case of Proximus and the new entrant. For other operators, all spectrum is allocated to 3G networks.
2,600 MHz			✓		
3,600 MHz				✓	

Table A.1: Relationship between spectrum bands and technology [Source: Axon].

Note: The relationship between the spectrum bands and the 2G and 3G technologies applies to an existing operator only

- **Unit costs**: The unit costs of the network elements included in the model (both unit CapEx and OpEx) have been updated to reflect the realities of the operators in Belgium in the context of this model. Three main changes have been made compared to the EC model:
  - **Reconciliation of the cost base for the year 2020.** The unit costs of some particular network elements have been adjusted to ensure the results of the model accurately reflect the costs borne by the different existing MNOs in Belgium. These adjustments have been carried out based on public financial information published by the mobile operators in Belgium.
  - **Update of costs for 5G network elements.** Considering the EC model did not include 5G networks, we have included the costs associated with the deployment of 5G network elements. These assets include (i) the cost of upgrading existing sites to be ready for 5G, (ii) the cost of deploying 5G carriers in said sites and (iii) the cost of upgrading the core network to be able to handle 5G traffic. The unit costs relating to these network elements are based on public data, as well as Axon’s proprietary data on the matter**.**
  - **Unit costs for spectrum to be awarded.** The deployment of 5G networks and the potential entry of a new operator likely involve the award of new spectrum, as well as the renewal of the licences for existing spectrum awarded (for further details on this matter, see Section 5). In this context, the unit costs for the bands that would potentially be awarded in such a process have been based on BIPT

[118] Only for Proximus and the new entrant.

information regarding the expected price a newcomer will probably pay to acquire such spectrum (for further details, please see Section 5).

- **Technical inputs**: The model includes additional technical inputs specific for 5G networks which were not present in the EC model (e.g., 5G voice bitrate, spectral efficiency, etc.). These inputs are based on the existing standards and academic papers.

- **Technology distribution**: Distribution of the demand of the different services to technologies has been adapted compared to the EC model, mainly due to the introduction of 5G networks in the cost model. In this context, separate migration patterns have been defined for voice and data services, to reflect the fact that likely data will move faster to 5G networks. Furthermore, it should be noted that the model considers different migration patterns for existing operators and for the new entrant.

  The figure below presents the technology distribution for data services defined for existing operators and the new entrant.

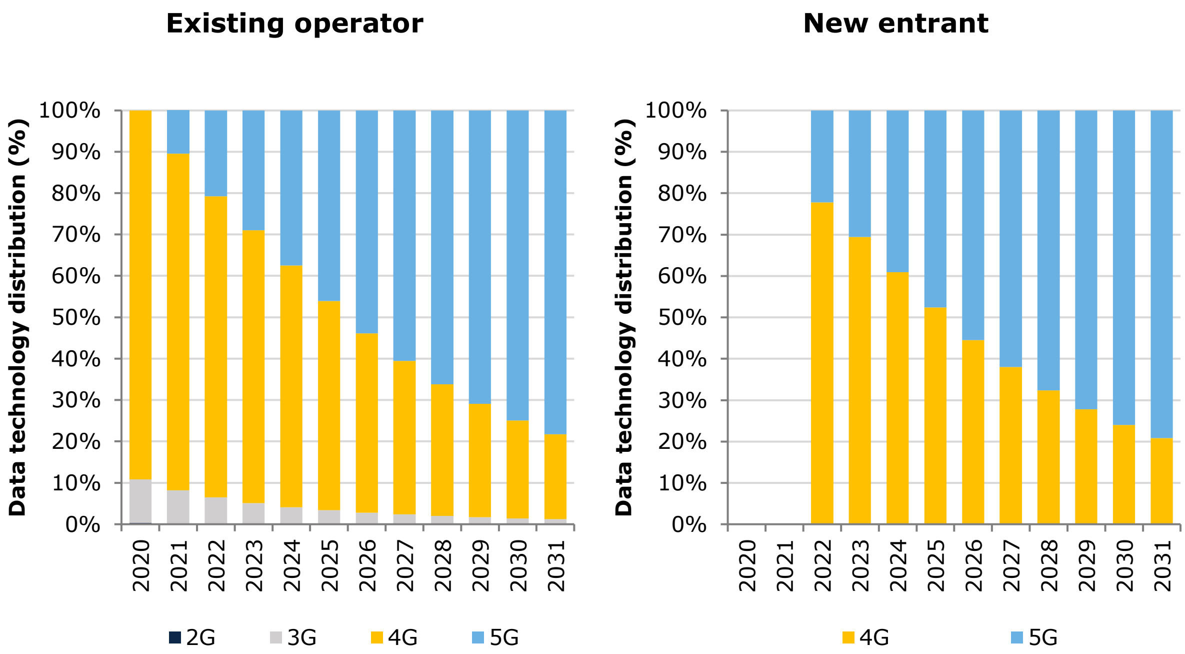

Figure A.6: Data demand distribution by technology for the whole modelled period [Source: Axon]

- **Geographical data**: To adjust the existing information to the needs of the cost model, we have carried out an exercise equivalent to the one carried out in the EC model but ensuring the disaggregation of the data introduced at a region level (i.e., Brussels-Capital Region, Flemish Region, Walloon Region).

  The figure below provides a disaggregation of Belgium's main population centres disaggregated by geotypes.

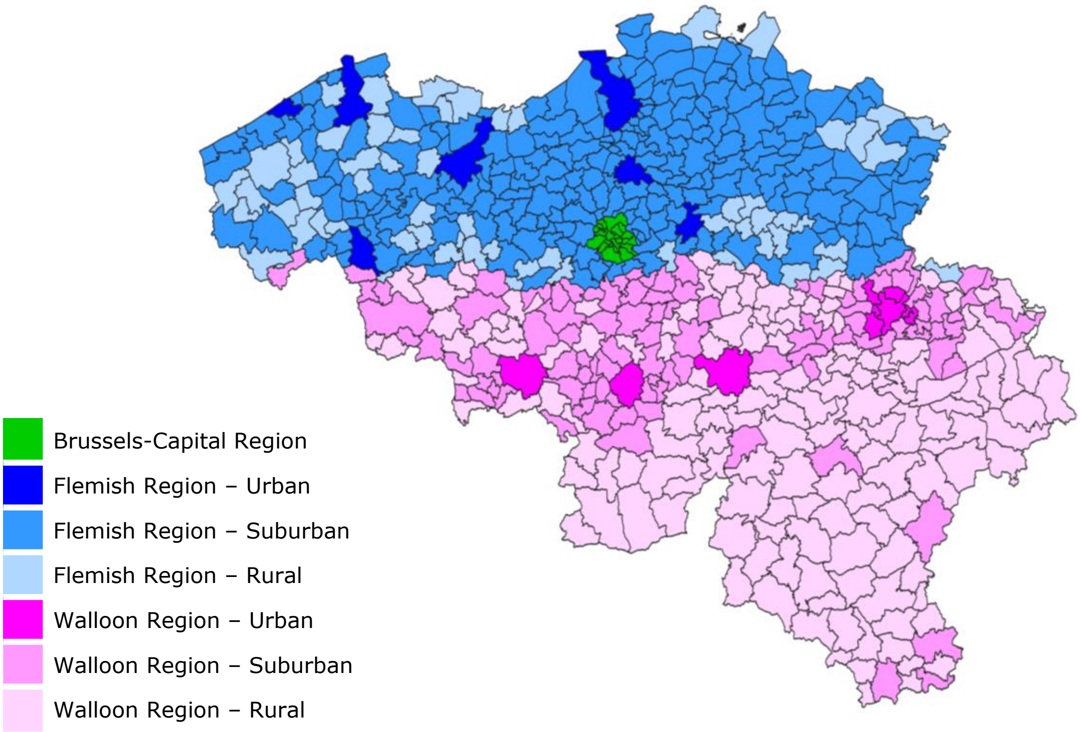

Figure A.7: Belgium map with the disaggregation of geotypes [Source: Axon]

- **Non-ionising radiation (NIR) limits**: As discussed in Subsection 3.1.4, the regulations on electromagnetic radiation in place in Belgium represent a very relevant aspect to consider for mobile network deployment in the country. For this reason, the cost model implements the different limits for non-ionising radiation (NIR) existing in each of the regions in Belgium. The implemented NIR limits affect the model in two main ways:
  - Limiting the effective cell radii of the mobile sites deployed. The model takes into account the NIR limit to determine the maximum power that a particular mobile installation can emit, which in practice affects its cell radii. To understand the relationship between power emitted and cell radii, the model implements the Okumura-Hata propagation model[119].
  - Determining which bands and technologies can be co-located. The model considers the NIR emissions of each technology, spectrum band and the existing network sharing to determine which technologies can be co-located in the same site.

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[119] Source: Hata, M. (August 1980). "Empirical Formula for Propagation Loss in Land Mobile Radio Services". IEEE Transactions on Vehicular Technology. VT-29 (3): 317–25.

The remaining inputs included in the cost model remain mostly unchanged compared to the previous model developed by the European Commission. For further details on this model, please see the relevant model reference documentation.[120] At the same time, with the exception of the necessary changes to introduce the additional features required for the new model, the calculations and algorithms employed are virtually the same as the ones included in the existing EC cost model.

Based on this background, once the relevant information has been updated in the model, the accuracy of the model was verified by assessing the differences between the results of the model in terms of the total number of sites per region and the cost base of the Belgian market according to the operators' financial statements.

- Number of access nodes per region:

Parameter (# of sites)	Belgian market	Model	Difference (%)
Brussels-Capital Region	1.370	1.236	-9,78%
Flemish Region	6.322	6.396	1,17%
Walloon Region	4.092	4.318	5,52%
Total	**11.784**	**11.950**	**1,41%**

Table A.2: Results of the reconciliation of sites of the model [Source: Axon]

- Cost base of the network elements:[121]

Parameter (EUR Million)	Belgian Market	Model	Difference (%)
Depreciation	235,8	242,4	2,81%
OpEx	320,2	328,2	2,52%
Total	**556,0**	**570,6**	**2,64%**

Table A.3: Results of the reconciliation of the cost base of the model[122] [Source: Axon]

The above table shows that the results of the model are ±10% of the actual values in the market in Belgium. For this reason, we consider that the results of the cost model fully reflect the realities of the Belgian market's mobile operators.

[120] Source: https://ec.europa.eu/newsroom/dae/document.cfm?doc_id=61085

[121] Excluding non-network elements and spectrum licences

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