aetha

Ensuring European spectrum renewals are aligned with Digital Decade targets

Report for Ericsson

1 October 2022

Contents

1. Executive summary 3
2. Introduction 13
3. Importance of spectrum in achieving Digital Decade and Green Deal targets 15
4. Best practices for spectrum pricing 28
5. Best practices for spectrum renewal processes 36
6. Conclusions 58

Annex A Upcoming spectrum renewals in Europe 61

1. Executive summary

1.1 Introduction

Aetha Consulting Limited (Aetha) has prepared this report for Ericsson to discuss how renewal processes for spectrum licences in Europe – including the pricing of spectrum – can be designed by policymakers to help achieve Europe's Digital Decade and European Green Deal targets.

Europe is aiming for digital transformation in the 2020s (the 'Digital Decade'), including the extension of high-speed fixed and mobile connectivity to all citizens. However, achieving this will require significant investment from operators at a time when they face major financial pressures due to stagnating revenues and increasing capital expenditure. One major component of capital expenditure contributing to this increase is the cost of spectrum, including one-off spectrum fees, annual licence fees and indirect licence costs, all of which contribute to the Total Cost of Spectrum Ownership (TCSO).

There are a large number of spectrum renewals set to occur in Europe in the coming years, providing an opportunity for policymakers to adjust spectrum licence terms, including the TCSO and its distribution between the three components outlined above. By doing so, regulators could ease financial pressure on operators and thereby promote investment to meet the Digital Decade and European Green Deal targets. In this report, we discuss best practices for spectrum renewal processes and spectrum pricing which, if followed, will enable policymakers to increase the likelihood of achieving their aims for the Digital Decade.

1.2 Importance of spectrum in achieving Digital Decade and Green Deal targets

1.2.1 Europe's Digital Decade

The European Commission (EC) has set out a vision for Europe's digital transformation by 2030, as well as the measures required to achieve this during the 2020s – the so-called 'Digital Decade'. The Digital Decade plans revolve around four cardinal points: skills, secure and sustainable infrastructures, digital transformation of businesses, and digitalisation of public services.

A key component is the development of secure and sustainable digital infrastructures, including the aim for all households to be covered by a Gigabit network and for all populated areas to be covered by 5G, by 2030[1]. The universal connectivity to be provided by this infrastructure is a key enabler for other areas of the 'Digital Decade' – without it, the other three cardinal points cannot be achieved.

Universal connectivity is also vital for creating a sustainable society – for example, it enables a multitude of new Internet of Things (IoT) applications with the potential to increase the efficiency of manufacturing, farming and transportation processes, saving energy and reducing waste. Indeed, a resilient telecoms infrastructure is a key component of United Nations Sustainable Development Goal (SDG) 9[2].

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[1] European Commission, '2030 Digital Compass: The European Way for the Digital Decade', March 2021. The forthcoming 2030 Policy Programme "Path to the Digital Decade", is likely to specify that "all populated areas are covered by next generation wireless high-speed networks with at least 5G equivalent performance."

[2] See European Commission, 'Communication from the Commission to the European Parliament, The Council, The European Economic and Social Committee and the Committee of the Regions: Next steps for a sustainable European future: European action for sustainability', COM(2016) 739 final, 22 November 2016 and United Nations General Assembly, 'Resolution adopted by the General Assembly on 25 September 2015: 70/1. Transforming our world: the 2030 Agenda for Sustainable Development', Reference A/RES/70/1, 21 October 2015.

The EC has outlined its sustainability vision for Europe within the 'European Green Deal', which aims for Europe to achieve net zero greenhouse gas emissions by 2050, making it the first climate-neutral continent.[3] The telecoms industry has a key role to play in achieving these goals – as highlighted by ETNO, high-quality telecoms networks are essential for the digitalisation of industry and will act as a catalyst for reaching these ambitious climate targets.[4] Digital technologies have the potential to increase efficiency and sustainability across all sectors of the economy but universal connectivity is essential for these benefits to be unlocked, maximising the chances of achieving the European Green Deal targets.

Data from the EC's Digital Economy and Society Index (DESI) report for 2022 indicates that fixed very high-capacity networks (VHCNs) cover 70% of European households, but only 37% of those in rural areas[5]. Meanwhile, 5G coverage across Europe continued to develop at the time of DESI's report which indicated that, as of mid-2021, 25 Member States had started commercial 5G network deployments, with the greatest coverage recorded in Italy, Denmark and the Netherlands (with over 90% of populated areas covered). Since then 5G deployment has continued – commercial 5G services are now available in all EU member states, with 64% of EU population covered as of July 2022.[6] However, we note that 5G is commonly deployed using either new low frequency spectrum (e.g. 700MHz) or existing 4G mid-band spectrum and Dynamic Spectrum Sharing (DSS) so, in many cases, will not yet be delivering a step-change in performance when compared to 4G networks.

Operators require a portfolio of low-, mid- and high-band spectrum to support high speeds, provide sufficient network capacity and enable network coverage to be provided in the most cost-effective way. Sufficient low frequency spectrum (below 1GHz) is needed to provide mobile services to areas (less populated areas, deep indoor areas) which higher frequency signals cannot reach.

To unlock the full benefits of 5G, including such a change in network performance, 5G needs to deployed by operators using a mix of low-band spectrum (e.g. 700MHz) for a coverage layer and a large contiguous block of mid-band spectrum (e.g. 100MHz from the 3.5GHz band) to offer high speeds across a wide area, supplemented with mmWave spectrum (e.g. 26GHz band) to provide sufficient capacity in very busy areas (e.g. transport interchanges, sports/entertainment arenas etc).

In the future, additional mid-band spectrum (e.g. upper 6GHz band) will be required to support traffic growth in city areas. GSMA Intelligence estimates that mid-band spectrum will generate around 63% of the total GDP uplift generated by 5G[7]. Additional low-band spectrum (e.g. 600MHz) will be needed to provide extra capacity in deep indoor and more rural areas that cannot be reached by mid-band spectrum and additional mmWave spectrum (e.g. 40GHz band) may also be required.

Despite the progress outlined above with regards to the deployment of 5G and fixed VHCNs, considerable investments will need to be made by both the telecoms industry and governments to achieve the EC's Digital Decade and European Green Deal targets, with public funding required to bridge the 'investment gap' where network deployment would otherwise be uneconomic.

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[3] European Commission, 'A European Green Deal', 7 June 2022.

[4] European Telecommunications Network Operators' Association (ETNO), 'ETNO unveils European telecoms contribution to EU Green Deal debate', 24 June 2020.

[5] European Commission, 'Digital Economy and Society Index (DESI) 2022: Thematic Chapters', 28 July 2022.

[6] VVA, PolicyTracker and LS telcom for the European 5G Observatory, '5G Observatory Quarterly Report 16, July 2022', 1 August 2022.

[7] GSMA Intelligence, 'The Socio-Economic Benefits of Mid-Band 5G Services', February 2022.

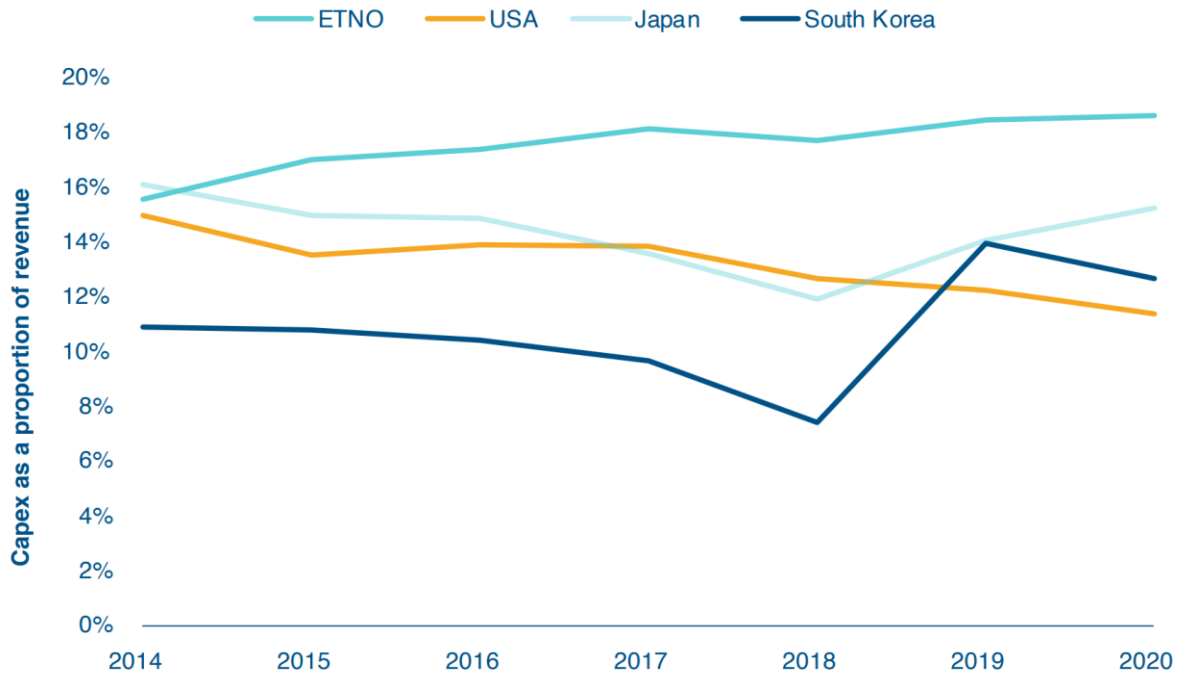
1.2.2 Financial challenges facing mobile operators

The public funding required to deliver on the Digital Decade and European Green Deal objectives depends on the industry's ability and economic incentive to fund network coverage expansion. However, operators are facing significant financial challenges. Mobile operators are currently making record investments in their networks due to:

- Investment in new 5G technology (radio access network and core network upgrades)
- The simultaneous operation of four generations of mobile technology (2G, 3G, 4G & 5G)
- Investment in new network architectures (e.g. small cells)
- The deployment of new sites to increase network coverage
- Spectrum acquisition costs.

However, this is occurring at a time mobile service revenues are flat lining (or even declining). The result is that capital intensity (capital expenditure as a proportion of revenue) is increasing, as shown in Figure 1-1, and margins are decreasing. This is clearly unsustainable in the long term.

Figure 1-1: Capital intensity of operators in home markets [Source: ETNO[8]]



1.2.3 Impact of upcoming spectrum renewals

One key area of expenditure is spectrum acquisition. As discussed in Section 1.3.1 below, this expense costs ~7% of mobile service revenue on average across Europe.[9] Given that the total capital intensity of European mobile operators is estimated at ~18% in Figure 1-1 above, spectrum costs are estimated to represent an average of ~35-40% of capital expenditure.

[8] ETNO, 'State of Digital Communications 2022', February 2022. ETNO members are mostly the main incumbent fixed telecoms operator in individual European countries – such operators typically operate a mobile business in their 'home' country and many also have mobile operations in other countries. The figure depicts the capital intensity of the members in their home markets.

[9] This estimate is based on analysis performed by Aetha Consulting and presented within Figure 4-3 of this report.

We highlight spectrum acquisition because the availability and price of spectrum are often under the direct control of regulators, in contrast to many of the other sources of financial pressure outlined above (e.g. revenue decline). It is therefore an area in which regulators can make a positive contribution towards easing operators' financial challenges, potentially increasing the investment they are able to make in other areas (e.g. 5G deployment) and reducing the investment gap.

As discussed above, operators require a portfolio of low-, mid- and high-band spectrum. In the future, operators will need to both acquire new spectrum and retain existing spectrum to maintain a competitive spectrum portfolio. Renewal is particularly important because (i) it affects operators' short-term ability to continue offering 2G, 3G & 4G services, and (ii) there are pre-existing equipment deployments so comparatively less capital expenditure is required to use the spectrum.

In addition, much spectrum is due for renewal in the next 10 years. We have analysed spectrum holdings in Europe, identifying licences which are due to expire in this period. The upcoming renewals are summarised in Figure 1-2 below, which shows the date of expiry for currently awarded spectrum in each of the 32 countries studied (European Economic Area (EEA) plus Switzerland and the UK). The expiry dates are colour-coded, with expiries in the next 2, 5 and 10 years shown in red, orange and yellow, respectively. Licences which are not due to expire in the next 10 years are shown in green, whilst grey is used to denote spectrum that is yet to be awarded for mobile in the country in question.

We have found that of the 32 countries studied, only two do not have any spectrum licences that expire in the next 10 years (Liechtenstein and the United Kingdom). Furthermore, we found that in eight countries (Czech Republic, Estonia, Iceland, Ireland, Lithuania, Poland, Romania and Spain), all spectrum licences expire in the next 10 years.

The bands which have the greatest number of expiring licences are 800MHz, 900MHz, 1800MHz, 2.1GHz and 2.6GHz – the 800MHz and 2.6GHz bands are key 4G bands, whilst the 900MHz and 2.1GHz are typically used for 2G and 3G, respectively. However, in the long-term, all spectrum is expected to be refarmed for 5G use.

The spectrum to be renewed commonly forms an integral part of operators' spectrum portfolios, without which they would be unable to offer a full set of services to customers. The loss of spectrum in key bands can be an existential threat to operators, as illustrated by the example of Tele2 in Norway which failed to re-acquire spectrum in the 900MHz band during an auction process in 2013, resulting in its exit from the Norwegian market. Due to the magnitude of these risks, a lack of information over how expiring spectrum licences will be re-assigned and the corresponding prices creates a huge amount of uncertainty, potentially impacting operators' ability/willingness to invest in their networks.

For the above reasons, it is important for operators to have confidence that spectrum renewal processes will enable them to retain key spectrum at a price that is affordable in the long term, so that they can divert their energy and investments into deploying 5G and enhancing mobile network coverage. In light of this, we focus our recommendations on renewal processes in this report, although many of the principles are equally applicable to new spectrum awards.

Figure 1-2: Summary of spectrum licence expiry dates in Europe [Source: European Communications Office[10,11] and European 5G Observatory[12]]

	700 MHz FDD	800 MHz	900 MHz	1500 MHz SDL	1800 MHz	1900 MHz TDD	2.1 GHz	2.3 GHz	2.6 GHz FDD	2.6 GHz TDD	3.5 GHz	26 GHz
Austria	2044	2029	2034	2044	2034		2044		2026	2026	2039	
Belgium		2033							2027	2027	2025	
Bulgaria			2024		2024		2025		2041		2041	
Croatia	2036	2024	2024		2024	2024	2024		2024		2023	2036
Cyprus	2041	2028	2023		2023		2023		2028	2028	2041	
Czechia		2029	2024		2024	2024	2024		2029	2029	2032	
Denmark	2040	2034	2040		2032			2027	2030	2030		2025
Estonia		2030	2030		2030	2030	2030	2030	2030	2030		
Finland	2033	2033			2033				2029	2029	2033	2033
France	2035	2032	2024		2024	2022	2030		2031		2023	
Germany	2033	2025	2033	2033	2025	2025	2025		2025	2025	None	
Greece		2030	2027		2027				2030	2029	2029	
Hungary		2029	2029		2034				2029	2029	2034	
Iceland	2032	2023			2023				2032			
Ireland		2030	2030		2030	2022	2022				2032	2028
Italy	2037	2029	2029	2029	2029		2029		2029	2029	2037	2037
Latvia	2042	2033	2026	2042	2026	2030	2027	2027	2028	2028	2025	
Liechtenstein		None	None		None		None		None			
Lithuania		2030	2032		2032		2026	2029	2027	2030	2022	
Luxembourg	2035	2027	2027		2027		2033		2027		2035	
Malta		2033	2026		2026	2022	2022		2033	2033	2036	
Netherlands	2040	2029	2030	2040	2029		2040		2030	2029		
Norway	2038	2033	2033		2028	2022	2032	2022	2022	2022	2022	2022
Poland			2023		2022	2022	2022			2024		
Portugal		2027	2027		2027				2027	2027	2025	
Romania		2029	2029		2029				2029	2029		
Slovakia	2040	2028	2026		2025		2026		2028	2028	2024	
Slovenia	2036	2029	2031	2036	2031		2023		2029	2029	2022	2036
Spain		2031	2028		2030				2030	2030	2030	
Sweden		2035	2025		2027	2025	2025	2045	2023	2023	2022	
Switzerland	2035	2028	2028	2035	2028		2028		2028	2028	2035	
UK	None	None	None	None	None	None	None	None	None	None	None	

[10] European Communications Office, 'ECO Report 03: The Licensing of "Mobile Bands" in CEPT', 9 March 2022.

[11] European Communications Office, 'ECO Report 03: The Licensing of "Mobile Bands" in CEPT', 6 April 2021.

[12] European 5G Observatory, 'Belgium grants provisional 5G licences in the 3.5GHz band', 15 May 2020.

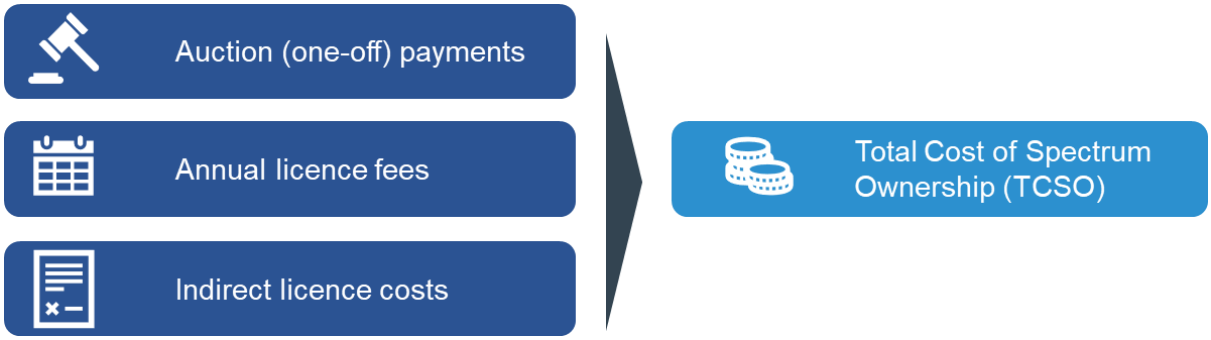
1.3 Best practices for spectrum pricing

Spectrum pricing is one area in which regulators can make a positive contribution towards easing operators' financial challenges, as highlighted above. **The availability and price of spectrum are often under the direct control of regulators**, in contrast to many of the other sources of financial pressure outlined above (e.g. revenue decline).

1.3.1 Total cost of spectrum ownership

For regulators to make positive decisions regarding spectrum pricing, it is important to consider all aspects of spectrum price; the Total Cost of Spectrum Ownership comprises several components:

Figure 1-3: Components of the Total Cost of Spectrum Ownership

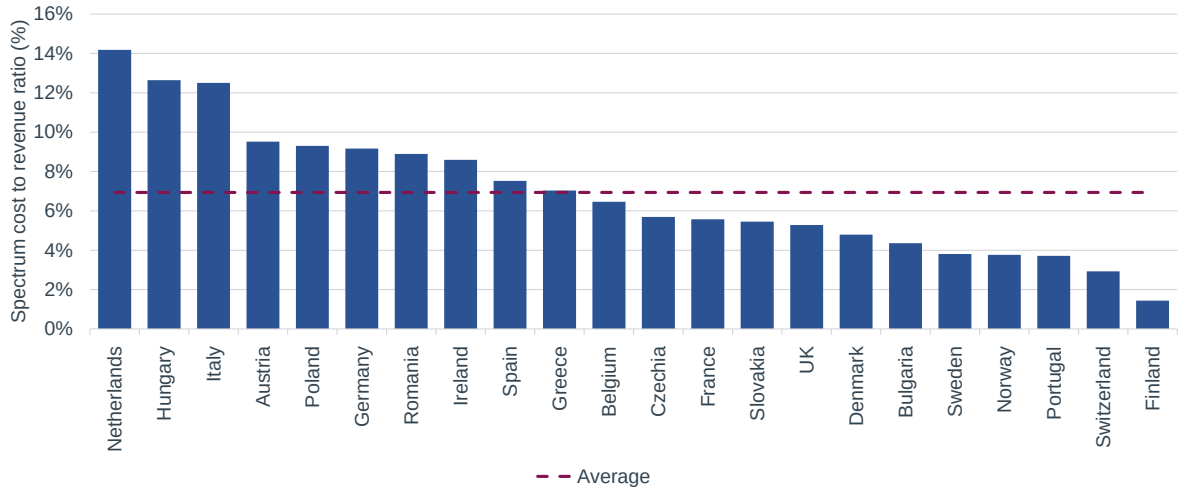


- **Auction (one-off) payments**: The amount of money determined by the award process, typically expressed as a one-off lump sum (although staggered payments are increasingly common).
- **Annual licence fees**: Annual spectrum fees are charged to cover the cost of administering the spectrum and are typically determined outside the award process.
- **Indirect licence costs:** Licences can contain specific obligations, for example to extend network coverage. The costs of these obligations can be difficult to quantify as they depend on the operators' private cost structures and network rollout ambitions; however, they can be significant.

The TCSO to a mobile operator is the sum of the three components. Therefore, an operator will only seek to acquire spectrum if the TCSO is lower than the spectrum's value to it. Consequently, the true 'reserve price' in an auction is the sum of the auction reserve price, annual licence fees over the licence period and indirect licence costs – if one is high, the others should be reduced to account for this.

One way of evaluating the impact of the cost of spectrum on mobile operators is to consider these costs as a percentage of operator revenues. The main limitation of this calculation is that it does not take account of indirect costs. However, it does provide a useful lower bound indication of the impact of spectrum costs on mobile operators. This is often a very significant expense – on average, European mobile operators are estimated to spend ~7% of revenue on spectrum, as shown in Figure 1-4 below.

Figure 1-4: Spectrum cost to revenue ratio [Source: Aetha]



Spectrum is a pre-requisite for the provision of mobile services – operators cannot exist without it – and therefore the fees associated with it can, to some extent, be considered to be an additional form of taxation on the industry – a 'spectrum tax'. This is particularly true of ongoing spectrum costs – specifically, annual licence fees and one-off fees for previously assigned spectrum – because whilst this spectrum is required for continuity of services and, over time, will be refarmed to the latest more spectrally efficient technologies, the spectrum on its own does not directly enable the provision of all new services or open up new revenue streams.

A large quantity of existing spectrum is due for renewal in Europe in the coming years, as highlighted in Figure 1-2 above. For this reason, close consideration of the link between the TCSO for expiring spectrum and investment incentives is required, in order for policymakers to help close the investment gap.

1.3.2 Risk and impact of high spectrum prices

One element to consider when renewing spectrum is spectrum pricing, including all components of the TCSO. High spectrum prices carry significant risks, having the potential to stymie investment and leave spectrum underutilised. **Therefore, it is essential that spectrum prices are set at a level which is affordable for operators in the long term and are aligned with policymakers' objectives.**

Operators are having to acquire new spectrum, as well as renew their existing spectrum holdings, in order to support traffic growth. At the same time, revenues are relatively static. Therefore, if spectrum continued to be awarded at the same price (per MHz), the overall spectrum cost (as a proportion of operator revenues) would increase. This is clearly unsustainable – as the amount of spectrum available increases, the unit price paid for spectrum (including all elements of the TCSO) has to decrease.

However, regulators often use the outcomes of historic auctions in the country as a basis for setting spectrum prices. This risks prices being set at excessive levels, potentially resulting in spectrum remaining unassigned (as has occurred in e.g. India, Thailand, Mexico, Romania). Even if the spectrum does sell, it may still be an inefficient outcome for the market that harms investment (e.g. Italy). For example, several studies have highlighted possible links between high spectrum prices and both reduced investment/network coverage and increased service prices:

- A study by NERA[13] found a modest correlation between higher prices for spectrum and both reduced network quality/availability (in terms of 3G/4G coverage, 4G subscribers and average speeds etc.), likely due to reduced network investment, and increased service prices. The results of this study were referenced within the GSMA's report on 'effective spectrum pricing'.[14]

- A report[15] produced by LS telcom, PolicyTracker and VVA for the European Commission suggested that there may be an inverse relationship between price paid for spectrum and network availability (i.e. higher auction prices are associated with lower 4G availability).

In summary, high spectrum prices can have a detrimental effect on network investment and service prices. With the increasing amount of spectrum required by operators to meet customer needs, unit prices for spectrum must go down – and therefore regulators should not continue to adopt the approach of using previous auction price outcomes to set reserve prices for upcoming auctions.

1.4 Best practices for spectrum renewal processes

There are many aspects that must be considered by regulators when re-allocating spectrum that has previously been assigned for mobile use, leading us to identify several areas of best practice:

- Timing of renewal process – Renewing spectrum in advance of licence expiry:
  - Renewal processes ought to be commenced well in advance of licence expiry, in order to limit the degree of uncertainty faced by operators and protect investor confidence – as set out in Article 45[16] and Article 50 of the European Electronic Communications Code (EECC)[17]
- Objectives of process – Ensuring the priorities/objectives for renewal are understood:
  - Regulators' priorities would be expected to include encouraging the growth and development of the mobile market, maintaining competition, and encouraging investment and innovation
    - These priorities are aligned with the provisions of the EECC, the objectives[18] of which include promoting access to and take-up of VHCNs, as well as competition and efficient investment, whilst contributing to the development of the internal market and promoting the interests of EU citizens

[13] NERA Economic Consulting, 'The Impact of High Spectrum Costs on Mobile Network Investment and Consumer Prices', May 2017.

[14] GSMA, 'Effective Spectrum Pricing: Supporting better quality and more affordable mobile services', February 2017.

[15] LS telcom, VVA and PolicyTracker for the European Commission Directorate General for Communication Networks, Content and Technology, 'Study on Spectrum Assignment in the European Union', October 2017.

[16] Article 45 of European Union, 'Directive (EU) 2018/1972 of the European Parliament and of the Council of 11 December 2018 establishing the European Electronic Communications Code', 17 December 2018, sets out that "[Member States shall …. by] (c) ensuring predictability and consistency in the granting, renewal, amendment, restriction and withdrawal of rights of use for radio spectrum in order to protect long-term investments."

[17] Article 50 of European Union, 'Directive (EU) 2018/1972 of the European Parliament and of the Council of 11 December 2018 establishing the European Electronic Communications Code', 17 December 2018, sets out that "National regulatory or other competent authorities shall take a decision on the renewal of individual rights of use for harmonised radio spectrum in a timely manner before the duration of those rights expired, …".

[18] See Paragraph 23 of European Union, 'Directive (EU) 2018/1972 of the European Parliament and of the Council of 11 December 2018 establishing the European Electronic Communications Code', 17 December 2018.

  - Regulators' priorities would not be expected to include the maximisation of spectrum assignment revenue (as per Best Practice 24 of the European Connectivity Toolbox[19]) as this is likely to detract from investments in operators' networks

- Conditions of spectrum use – Specifying an appropriate licence duration:
  - Renewed licences should be as long as possible, ideally indefinite, to provide certainty for investors by allowing a longer amortisation period and avoiding 'dead periods' before expiry. At a minimum, licences should have a duration of 20+ years as set out in Article 49(2)[20] of the EECC.
  - Ideally long spectrum durations should be coupled with allowing operators to trade spectrum, since the adoption of extended licences, particularly indefinite licences, has been shown to promote spectrum trading (e.g. in the UK & USA) and thereby increase the efficiency of spectrum use

- Design of renewal process – Selecting an appropriate award process:
  - Whilst auctions are increasingly the default approach for assigning mobile spectrum, and are a very useful tool, sometimes simple administrative extension/renewal processes may be appropriate in cases where demand does not outstrip supply, and may involve either the equal distribution of spectrum in the band to all operators or direct renewal of the existing holdings of each operator
    - Regulators may seek discussions with industry regarding how its priorities may be achieved through an administrative renewal process (e.g. in terms of expanding network coverage in exchange for reduced spectrum fees or rebalancing spectrum holdings between operators)
  - Auction processes are likely to be appropriate where demand for spectrum exceeds supply
    - Policymakers should focus on the main objectives of the award process, and not get distracted by the dynamics of the auction process itself – the primary objective should be to encourage competition and investment in the mobile market to meet mobile connectivity objectives, not to create artificial competition in the auction
  - Partial renewal is likely to be appropriate in cases where demand for spectrum exceeds supply but there is a business continuity risk to existing licensees if they lose key spectrum
    - The guaranteed renewal of part of an operator's spectrum holdings would significantly de-risk the process by addressing concerns regarding business continuity and ensuring the future availability of existing technologies (e.g. 2G/3G) – as required by Article 50(2)[21] of the

[19] European Union Connectivity Special Group, 'Common Union Toolbox for Connectivity', March 2021.

[20] Article 49(2) of European Union, 'Directive (EU) 2018/1972 of the European Parliament and of the Council of 11 December 2018 establishing the European Electronic Communications Code', 17 December 2018, sets out that "Where Member States grant individual rights of use for radio spectrum for which harmonised conditions have been set by technical implementing measures in accordance with Decision No 676/2002/EC in order to enable its use for wireless broadband electronic communications services ('wireless broadband services') for a limited period, they shall ensure regulatory predictability for the holders of the rights over a period of at least 20 years regarding conditions for investment in infrastructure which relies on the use of such radio spectrum, taking account of the requirements referred to in paragraph 1 of this Article."

[21] Article 50(2) of European Union, 'Directive (EU) 2018/1972 of the European Parliament and of the Council of 11 December 2018 establishing the European Electronic Communications Code', 17 December 2018, sets out that "In taking a decision pursuant to paragraph 1 of this Article, competent authorities shall consider, inter alia: ….. (f) the need to avoid severe service disruption.'

EECC which requires policymakers "to avoid severe service disruption" when renewing spectrum rights

- Such an approach would only be appropriate in situations where the partial renewal is economically efficient and do not risk distorting competition in the mobile market
- This approach is particularly important in the short-term where specific technologies (2G/3G) can only be deployed in particular frequency bands

- Auction best practices – Where an auction is required, adopting best practice approaches including:
  - Avoiding risky or complex auction formats/rules:
    - If an auction is deemed necessary, the auction design should take account of the risks and uncertainties that the mobile operators are facing in a spectrum renewal process
    - To reduce the uncertainty faced by operators when seeking to re-acquire previously licensed spectrum, we recommend using simple 'tried and tested' formats (e.g. Simultaneous Multi Round Ascending Auction (SMRA), Clock) and avoiding the use of formats which yield highly uncertain outcomes (e.g. Combinatorial Clock Auction (CCA))
  - Ensuring that auctions do not unduly impact on natural evolution of the market:
    - Where auctions are deemed necessary, we recommend that the auction rules do not prevent natural market evolution (e.g. forcing a new entrant through a spectrum reservation)
  - Prioritising non-monetary objectives, such as coverage:
    - If expanding coverage is an objective, regulators should consider accepting lower spectrum fees in return for operator commitments to expanding mobile coverage/5G deployment etc. Article 42(2)[22] of the EECC sets out that regulators should take account of the licence conditions when setting reservice prices for spectrum.

Overall, renewing spectrum with extended licence periods, well ahead of licence expiry, using either administrative licence renewals where demand does not exceed supply or simple auctions which guarantee partial renewal where demand does exceed supply, would have several benefits. It would avoid "investment hesitancy" on equipment using the spectrum in the years prior to licence expiry, as well as avoiding putting historic investments at risk. In addition, it would reduce the level of risk/uncertainty perceived by mobile operators with expiring spectrum licences, thereby releasing funding for strategic investments such as increasing network coverage.

[22] Article 42(2) of European Union, 'Directive (EU) 2018/1972 of the European Parliament and of the Council of 11 December 2018 establishing the European Electronic Communications Code', 17 December 2018, sets out that "With respect to rights of use for radio spectrum, Member States shall seek to ensure that applicable fees are set at a level which ensures efficient assignment and use of radio spectrum, including by: (a) setting reserve prices as minimum fees for rights of use for radio spectrum by having regard to the value of those rights in their possible alternative uses; (b) taking into account costs entailed by conditions attached to those rights; and (c) applying, to the extent possible, payment arrangements linked to the actual availability for use of the radio spectrum."

2. Introduction

Aetha Consulting Limited (Aetha) has prepared this report for Ericsson to discuss how renewal processes for spectrum licences in Europe – including the pricing of spectrum – can be designed by policymakers to help achieve Europe's Digital Decade European Green Deal targets.

2.1 Background

The European Commission (EC) has set out a vision for Europe's digital transformation by 2030 as well as the measures required to achieve this during the 2020s – the so-called Digital Decade. The Digital Decade plans revolve around four cardinal points: skills, secure and sustainable infrastructures, digital transformation of businesses, and digitalisation of public services.

A key component is the development of secure and sustainable infrastructures, including aims for all households to be covered by a Gigabit network and all populated areas to be covered by 5G, by 2030[23]. As well as ensuring all citizens and businesses can access the benefits of digitalisation, e.g. in terms of increased productivity, universal connectivity – particularly 5G connectivity – is vital for creating a sustainable society. The EC has outlined its sustainability vision for Europe within the 'European Green Deal', which aims for Europe to achieve net zero greenhouse gas emissions by 2050, making it the first climate-neutral continent.[24] Expanding connectivity is key to achieving this aim.

The achievement of such targets will require considerable investment by both the telecoms industry and governments – with public funding required to close the 'investment gap' and bring connectivity to areas where network deployment would otherwise be uneconomic, thereby unlocking the full productivity and sustainability benefits of digitalisation. The greater investment made by the telecoms industry, the smaller the 'investment gap' which needs to be closed using public funds.

A key factor impacting operators' ability to invest is certainty over the regulatory environment in which they operate – the greater the level of certainty, the greater the level of investor confidence and therefore the greater the levels of investment that can be made. In respect of mobile service provision (including 5G), regulatory certainty over radio spectrum availability is critical.

Radio frequencies are a key input to mobile services – too little spectrum and mobile operators will incur additional costs to carry the traffic generated, for example, by smartphone applications used by consumers and businesses. Mobile operators are not awash with funds at present – the investment climate is very tight – so any money spent on expanding network capacity which could have been saved through access to spectrum reduces the funding available for network investment to address Digital Decade and European Green Deal targets. Furthermore, any money spent by operators on 'unnecessarily expensive' spectrum reduces available funds for network investment.

The expense of spectrum is not limited to auction payments, however. There are multiple additional costs associated with spectrum acquisition, including annual licence fees and licence obligation costs, all of which contribute to the Total Cost of Spectrum Ownership (TCSO). All of these must be considered when determining spectrum prices, with the objective being to ensure that the total is not excessive. Only by doing so is it possible to avoid spectrum being 'unnecessarily expensive' and thereby protect

[23] European Commission, '2030 Digital Compass: The European Way for the Digital Decade', March 2021. The forthcoming 2030 Policy Programme "Path to the Digital Decade", is likely to specify that "all populated areas are covered by next generation wireless high-speed networks with at least 5G equivalent performance."

[24] European Commission, 'A European Green Deal', 7 June 2022.

operators' ability to fund network investments, including those associated with achieving Digital Decade and European Green Deal targets.

Mobile operators regularly invest in spectrum to deploy new technologies such as 5G and support traffic growth. Operators face an additional challenge as many of their existing spectrum licences are due to expire. Operators therefore face huge uncertainty over whether and on which (financial) terms they will be able to continue using this spectrum, which is key for service continuity. Until they have certainty on the renewals, operators will be hesitant to further invest in networks as they seek to avoid inefficient investments in case the renewals do not occur as envisioned.

In this paper, we therefore set out a series of recommendations for policymakers in relation to spectrum renewals, both in terms of spectrum pricing and award format. We set out best practice approaches which will significantly reduce the level of risk and uncertainty facing mobile operators, which in turn will mean that their attention can be focused on expanding network coverage to meet the Digital Decade targets, thus minimising the investment gap that the government/public need to fund.

We urge policymakers to consider our recommendations and signal intentions to adopt the suggested approaches to the mobile industry as early as possible, allowing the industry to have the confidence to make the required investments for achieving universal 5G coverage.

2.2 Structure of this document

The remainder of this document is structured as follows:

- Section 3 further discusses the importance of spectrum in achieving universal coverage and the challenges currently facing mobile operators, particularly with regards to the cost of spectrum
- Section 4 presents our recommendations with regards to spectrum pricing, in consideration of all components of the TCSO and the risks of policymakers setting excessive spectrum prices
- Section 5 presents our recommendations, based on best practices, in relation to the renewal of expiring spectrum licences
- Section 6 summarises the conclusions of our assessments.

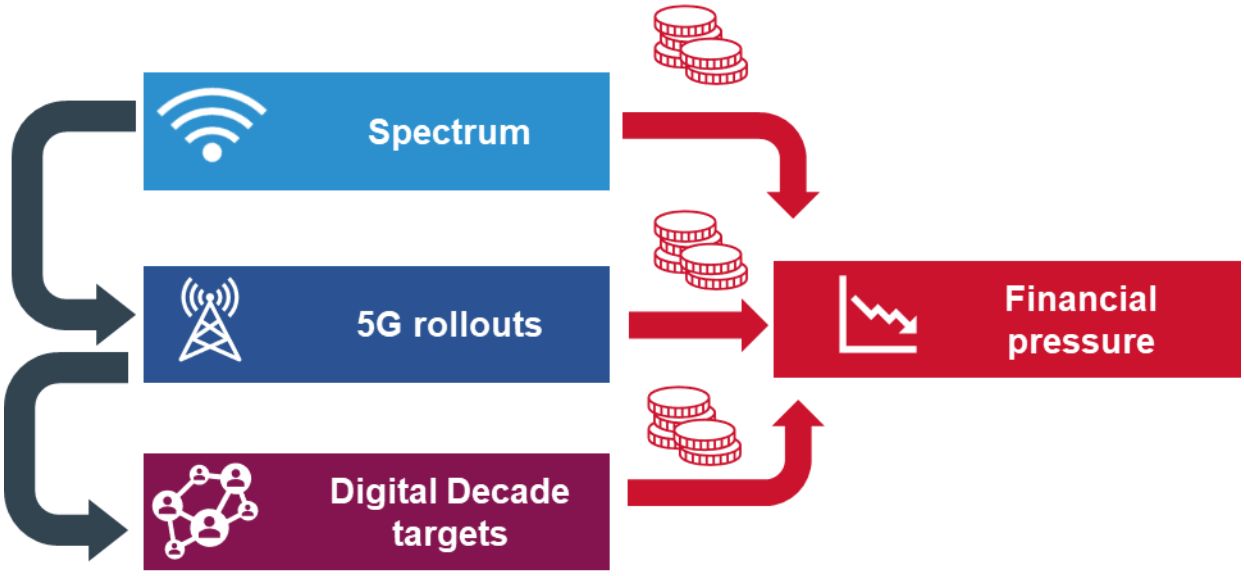
3. Importance of spectrum in achieving Digital Decade and Green Deal targets

The EC has declared the 2020s to be a 'Digital Decade', outlining ambitious connectivity targets that it aims to achieve by 2030 (Section 3.1). It has also published its 'European Green Deal', which outlines ambitious sustainability targets for 2050 – connectivity is expected to play a key role in enabling Europe to meet these targets. In order to achieve these targets, operators will need to further deploy 5G networks, for which spectrum is a key input. There are significant investments required in acquiring spectrum, rolling out networks and achieving the Digital Decade and European Green Deal targets, all of which add to the financial pressures that operators are currently feeling (Section 3.2) and which will negatively impact operators' willingness and ability to invest, thereby increasing the risk of Europe missing its connectivity targets.

One source of financial pressure on operators is the investment required to acquire spectrum. Spectrum pricing lies within policymakers' control. Therefore, it is one means by which policymakers may ease the financial pressure on operators, thus facilitating investments in universal connectivity. In Europe, the majority of existing spectrum licences are due expire in the coming years, after which they are expected to be re-allocated through so-called renewal processes. It is therefore important to understand the specific impact that these renewals will have on the ability and willingness of operators to invest in networks, as well as the licence and award conditions which will need to be in place for renewals to contribute to meeting the Digital Decade and European Green Deal targets (Section 3.3).

This complex interaction and the specific role that spectrum plays in this context has been summarised in Figure 3-1 below – we will discuss each of the components in more detail in this chapter.

Figure 3-1: The role of spectrum in achieving the Digital Decade targets and the factors contributing to the financial pressure on operators



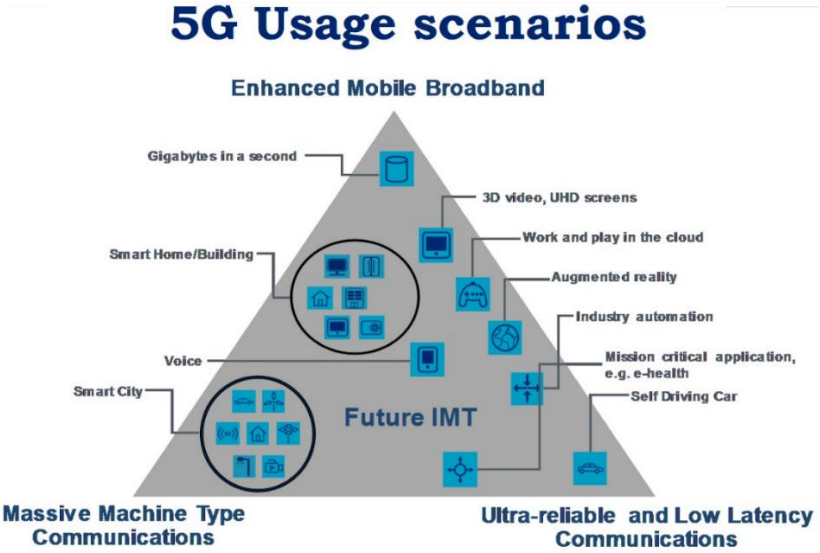
3.1 Europe's Digital Decade

The EC has set out a clear ambition for all European households to be covered by a Gigabit network and all populated areas to be covered by 5G, by 2030. Universal connectivity is a key enabler of other

areas of the 'Digital Decade' – without it, the other three cardinal points cannot be achieved, and businesses and citizens of the European Union will not be able to fully participate in the digital world.

In particular, we note the potential for the deployment of 5G to further enable access to key information, education and entertainment resources for citizens, as well as new business applications that will increase productivity and drive economic growth, additionally it support Europe to fulfil net zero goals by digitalization of industries. 5G networks do not just provide an economic boost to the telecoms sector but to the wider economy. 5G improves upon 4G in three main areas: enhanced mobile broadband, ultra-reliable low-latency communication and massive machine-type communication. These three components are known as the 5G triangle, as shown in Figure 3-2.

Figure 3-2: The 5G triangle [Source: ITU[25]]



- Enhanced mobile broadband refers to data speeds, which are expected to be around 20 times faster than for 4G. The actual speed of a 5G connection depends on the frequency of spectrum used. As the International Telecommunication Union (ITU) has defined[26], the total capacity for a single 5G mobile cell must be at least 20Gbps in download and 10Gbps in upstream. Furthermore, ITU has also defined the "per-user" speed for downloads as 100Mbps and uploads as 50Mbps. According to industry expectations, the mobile cell speed will increase up to 100Gbps in the future.

- Ultra-reliable low-latency communication is extremely important for time-critical applications like gaming. Low latency will also play an important role in many business applications – for example, in Automated-Guided Vehicles (AGV), manufacturing plants or warehouses. In current 5G deployments, latency of approximately 30ms is achieved, while some optimisations (e.g. operating in the edge cloud field) could realistically see a latency as low as 10ms. Latencies below 10ms are possible under lab conditions and the long-term target is to achieve 1ms, however this may be extremely challenging in reality.

- Massive machine type communication refers to support for the growing number of IoT devices that are all communicating with each other. Connection density is expected to be a major consideration for 5G that has never been as much of an issue for previous generations. Statistica, for example, predicts that the ratio of IoT connected devices per human on the planet will increase from the two

[25] ITU, 'Emerging Trends in 5G/IMT2020', September 2016.

[26] ITU, 'Minimum requirements related to technical performance for IMT-2020 radio interface(s)', 22 February 2017.

per person today to ten per person by 2025.[27] For a future smart city with connected traffic lights, parking lots and meters (gas, water, power), the approximately 2000 active users per square kilometre envisaged in 4G is very different from the assumptions made in developing the IMT-2020 standard where 5G aims to support at least one million connections per square kilometre.[28]

As a consequence of these new capabilities, 5G is expected to impact on many different industries, driving new processes and productivity growth. Some examples include:

- Agriculture: Monitoring and control
- Education: New learning opportunities enabled by Augmented Reality and Virtual Reality applications
- Health: Remote diagnosis, Telemedicine
- Logistics and transportation: Smart ports, autonomous connected vehicles
- Manufacturing: Automated robots and vehicles
- Public sector: Access to e-services
- Professional services: Improved remote workforce productivity.

Providing universal connectivity, particularly 5G connectivity, is also vital for creating a sustainable society – for example, it enables a multitude of new Internet of Things (IoT) applications with the potential to increase the efficiency of manufacturing, farming and transportation processes, saving energy and reducing waste. Indeed, a resilient telecoms infrastructure is a key component of United Nations Sustainable Development Goal (SDG) 9[29].

The EC has outlined its sustainability vision for Europe within the 'European Green Deal', which aims for Europe to achieve net zero greenhouse gas emissions by 2050, making it the first climate-neutral continent.[30] The telecoms industry has a key role to play in achieving these goals – as highlighted by ETNO, high-quality telecoms networks are essential for the digitalisation of industry and will act as a catalyst for reaching these ambitious climate targets.[31] We illustrated the potential of digital technologies to increase efficiency and sustainability across all sectors of the economy above. However, universal connectivity is essential for these benefits to be unlocked, maximising the chances of achieving the European Green Deal targets.

Member States are currently in very different positions in respect of the 2030 connectivity targets. Figure 3-3 shows the coverage of fixed very high-capacity networks (VCHNs) in mid-2022 as a percentage of households, as presented in the EC's Digital Economy and Society Index (DESI) report for 2022.

[27] Statistica, 'Number of IoT connected devices worldwide 2019-2030', 19 October 2021.

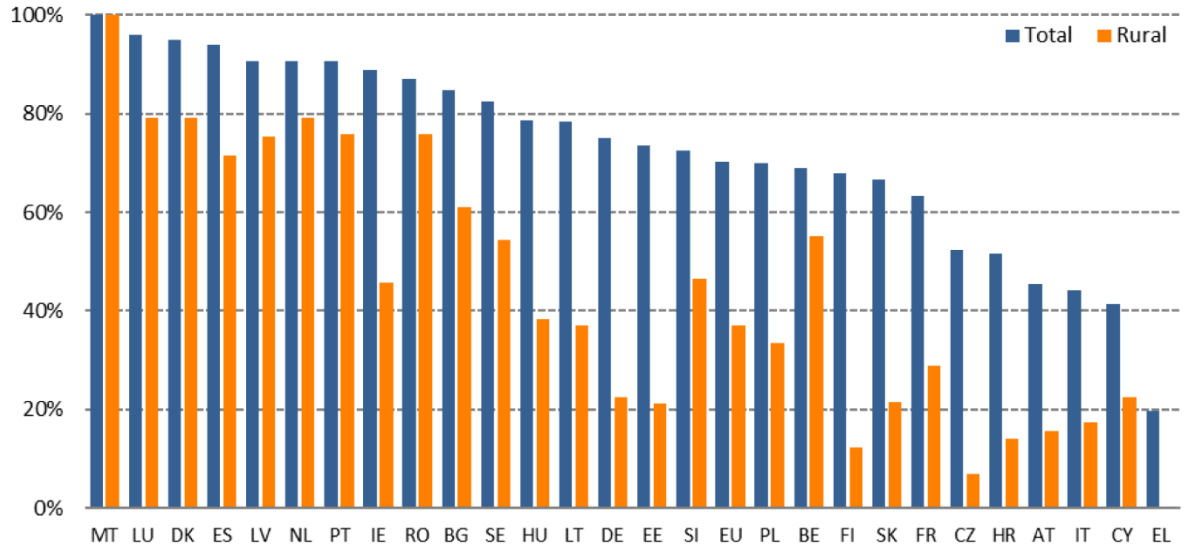
[28] ITU, 'Key features and requirements of 5G/IMT-2020 networks', 14 February 2018.

[29] See European Commission, 'Communication from the Commission to the European Parliament, The Council, The European Economic and Social Committee and the Committee of the Regions: Next steps for a sustainable European future: European action for sustainability', COM(2016) 739 final, 22 November 2016 and United Nations General Assembly, 'Resolution adopted by the General Assembly on 25 September 2015: 70/1. Transforming our world: the 2030 Agenda for Sustainable Development', Reference A/RES/70/1, 21 October 2015.

[30] European Commission, 'A European Green Deal', 7 June 2022.

[31] European Telecommunications Network Operators' Association (ETNO), 'ETNO unveils European telecoms contribution to EU Green Deal debate', 24 June 2020.

Figure 3-3: Fixed very high-capacity network coverage in mid-2021 (% of households) [Source: European Commission DESI[32]]



Overall coverage of VHCNs in mid-2021 amounted to 70% of European households, but only 37% in rural areas. The lowest levels of coverage as of mid-2020 were in Greece, Cyprus, Italy and Austria.

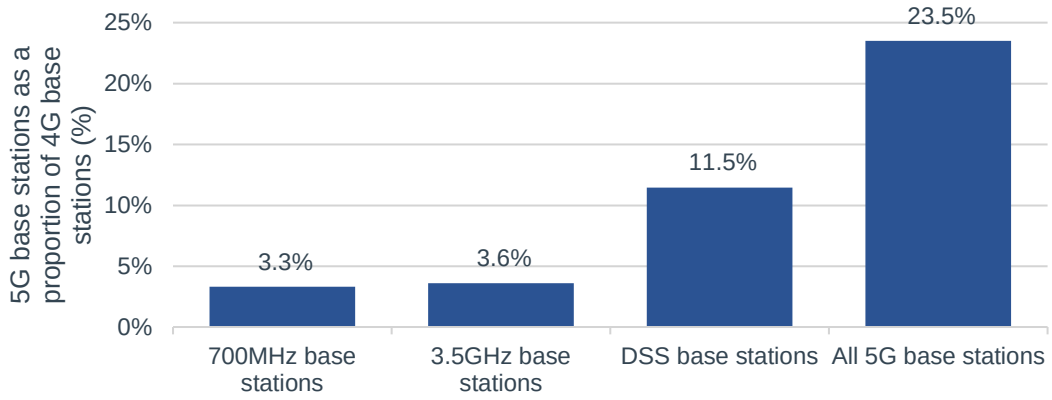
The Digital Decade ambition for universal 5G coverage built upon the EC's 2016 target[33] for all urban areas and major transport paths to have uninterrupted 5G coverage by 2025. 5G network coverage across Europe continued to develop at the time of the DESI 2022 report which indicated that, as of mid-2021, 25 Member States had started commercial 5G network deployments, with the greatest coverage recorded in Italy, Denmark and the Netherlands (with over 90% of populated areas covered). Since then 5G deployment has continued – commercial 5G services are now available in all EU member states, with 66% of EU population covered as of July 2022.[34] In total, ~150k 5G base stations have now been deployed in EU member nations, equating to ~24% of 4G base stations, as shown in Figure 3-4 below.

[32] European Commission, 'Digital Economy and Society Index (DESI) 2021: Thematic Chapters', 28 July 2022.

[33] See European Commission, 'Communication from the Commission to the European Parliament, The Council, The European Economic and Social Committee and the Committee of the Regions: Connectivity for a Competitive Digital Single Market – Towards a European Gigabit Society', COM(2016) 587 final, 14 September 2016 and European Commission, 'Communication from the Commission to the European Parliament, The Council, The European Economic and Social Committee and the Committee of the Regions: 5G for Europe – An Action Plan', COM(2016) 588 final, 14 September 2016.

[34] VVA, PolicyTracker and LS telcom for the European 5G Observatory, '5G Observatory Quarterly Report 16, July 2022', 1 August 2022.

Figure 3-4: 5G base stations in European Union member states as a proportion of existing 4G base stations (end 2021) [Source: European 5G Observatory[34]]



However, we note that 5G is commonly deployed using either new low frequency spectrum (e.g. 700MHz) or existing 4G mid-band spectrum and Dynamic Spectrum Sharing (DSS), as illustrated in Figure 3-4 above. As a result, 5G will not yet be delivering a step-change in performance when compared to 4G in many cases. This is the case, for example, in the Netherlands. The reported coverage of over 90% of populated areas is likely to have been based on the deployment of 5G technology using spectrum below 3GHz – therefore, the user-experienced speeds are likely to be lower than where 3.5GHz has been deployed. As discussed in Section 3.3 below, new spectrum bands are required to enable the full benefits of 5G to be realised.

In order to achieve the Digital Decade's target of 100% 5G population coverage, operators need to:

- Deploy 5G technology on existing sites (where 2G, 3G and 4G have been deployed)
- Deploy 5G technology on new sites (in areas the operator does not currently provide services)

Especially the latter rollouts are very expensive for operators because these areas have often remained uncovered because they are not commercially viable due to low network usage – the operators would need to make 'loss-making' investments to provide coverage, so government support (e.g. financial aid) is required.

3.2 Financial challenges facing mobile operators

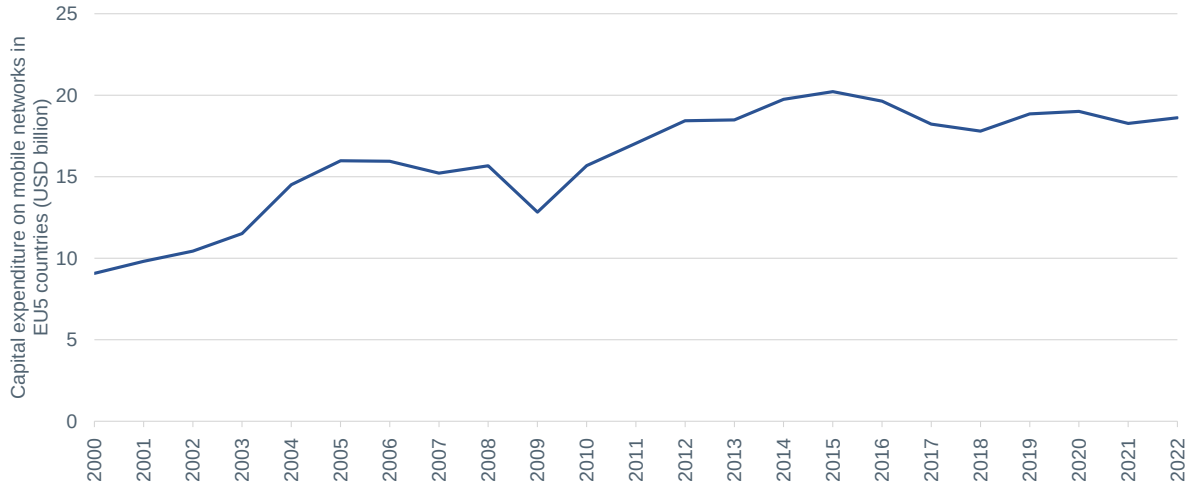
Given the significant investment required in deploying networks in commercially unviable areas, the Digital Decade target of universal connectivity can only be met through a combination of incentivising private investment to a maximum and leveraging public funding to bridge remaining coverage gaps. The funding required from the public (the so-called 'investment gap') depends on the extent to which the telecoms industry can fund network coverage expansion, including 5G deployments.

Mobile operators are making record investments in their networks at present – see, for example, the annual capital expenditure by mobile operators in EU5 countries (France, Germany, Italy, Spain and the United Kingdom) in Figure 3-5. Such high levels of investment are arising as a consequence of:

- The requirement to **invest in new 5G technology** – including both radio access network (RAN) and core network upgrades (incl. virtualisation of the core) to support new services which require features such as low latency, network slicing etc.

- The requirement for operators to **operate four generations of mobile technology in parallel** – 2G, 3G, 4G & 5G. Operators are increasingly planning to shut down 3G around 2025 but 2G will be needed for some time yet to support users/devices (incl. M2M) which are incompatible with 4G/5G.
- **Investing in new network architectures** – as mobile traffic grows, investments need to be made in deploying additional spectrum, plus moving to a small-cell architecture in the densest areas.
- **Deploying new sites to increase network coverage** – there are coverage gaps in operators' coverage footprints and investment in new sites is required to close these gaps. This is in addition to the additional sites that need to be deployed to extend network coverage in less populated areas.
- The cost of **spectrum acquisition** – This is a key expenditure, as we discuss further below.

Figure 3-5: Annual capital expenditure (excluding spectrum acquisition costs) on mobile networks in EU5 countries[35] [Source: GSMA Intelligence[36]]

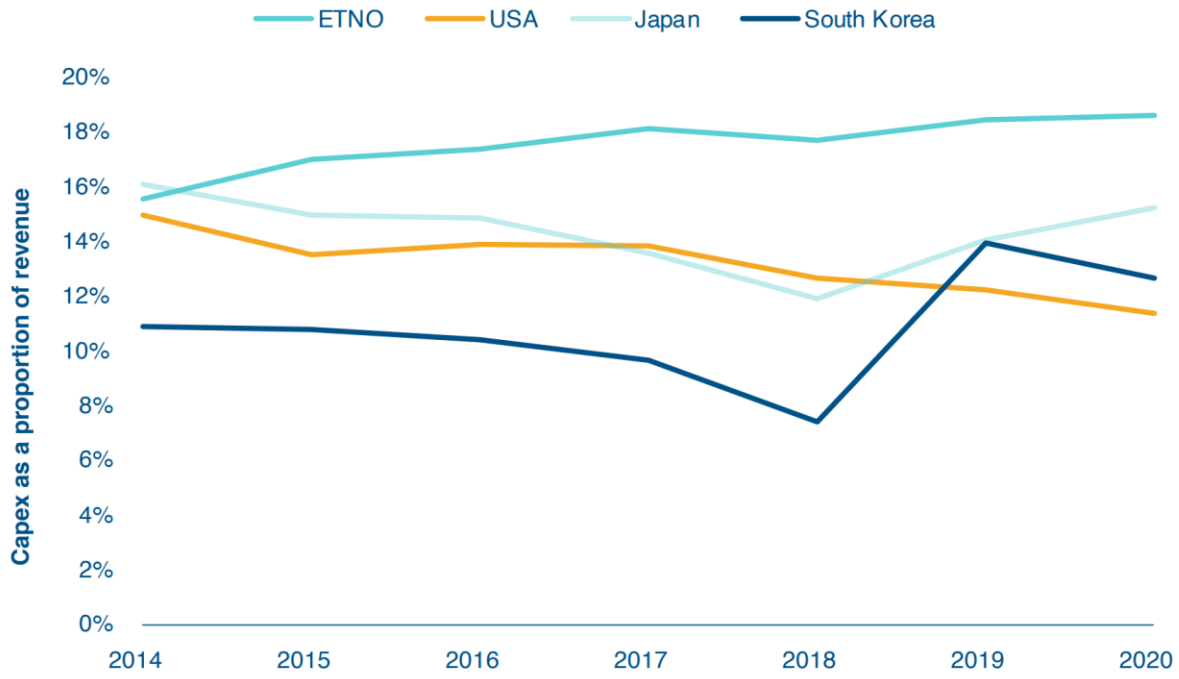


This peak in capital expenditure is occurring at a time when operators' revenues are flat-lining (or even declining) – the surge in traffic has not translated into increased spending on mobile services. This is illustrated in Figure 3-6, which shows the capital intensity (capital expenditure as a proportion of revenue) for European Telecommunications Network Operators Association (ETNO) members from 2014-2020, compared to that for operators in the USA, Japan and South Korea. The capital intensity of European operators increased during this period and is above that in the USA, Japan and South Korea.

[35] EU5 is used to refer to the five largest countries in Europe, namely France, Germany, Italy, Spain and the United Kingdom.

[36] GSMA Intelligence, 'Financial – Cost & Profitability. Total Capex', Accessed 17 May 2022.

Figure 3-6: Capital intensity of operators in home markets [Source: ETNO[37]]



The combination of these factors has meant that operators' margins have also reduced. For example, McKinsey reported that from 2007-2018, European operators suffered a 24% reduction in revenue, resulting in a 6 percentage-point reduction in EBITDA margin.[38] Such reductions are clearly unsustainable in the long term and the situation will further worsen with the rising cost of debt.

3.3 Impact of upcoming spectrum renewals

We outlined the key contributions to mobile operators record investments above, one of which is spectrum acquisition. Spectrum is a major area of investment for mobile operators and is sometimes described as the 'lifeblood' of a mobile network. We examine the magnitude of the spectrum acquisition costs faced by mobile operators within Section 4.1.

We highlight spectrum acquisition because the availability and price of spectrum are often under the direct control of regulators, in contrast to many of the other sources of financial pressure outlined above (e.g. revenue decline). It is therefore an area in which regulators can make a positive contribution towards easing operators' financial challenges, potentially increasing the investment they are able to make in other areas (e.g. 5G deployment) and reducing the investment gap.

Operators require a portfolio of low-, mid- and high-band spectrum to support high-speeds to customers, provide sufficient network capacity and enable network coverage to be provided to less populated areas in the most cost-effective way. Sufficient low frequency spectrum (below 1GHz) is needed to provide mobile services to areas (less populated areas, deep indoor areas) which higher frequency signals

[37] ETNO, 'State of Digital Communications 2022', February 2022. ETNO members are mostly the main incumbent fixed telecoms operator in individual European countries – such operators typically operate a mobile business in their 'home' country and many also have mobile operations in other countries. The figure depicts the capital intensity of the members in their home markets.

[38] McKinsey & Company, 'Telecom operators: Surviving and thriving through the next downturn', August 2019.

cannot reach. Looking forward, European mobile operators both need to acquire spectrum in new bands and also seek to renew their existing spectrum holdings.

- **New spectrum** is required to enable the deployment of new services and to achieve full 5G performance.
  - For example, initial full deployment of 5G requires operators to acquire 700MHz spectrum (for a low frequency coverage layer), a large contiguous block (e.g. 100MHz) of 3.5GHz spectrum (to offer high-speed services across a wide area) and 26GHz spectrum (to provide sufficient capacity in very busy areas (e.g. transport interchanges, sports/entertainment arenas etc)).
  - In the future, additional mid-band spectrum (e.g. upper 6GHz band) will be required to support future traffic growth in city areas; GSMA Intelligence estimates that mid-band spectrum will generate around 63% of the total GDP uplift generated by 5G[39]. Additional low-band spectrum (e.g. 600MHz) will be needed to provide extra capacity in deep indoor and more rural areas that cannot be reached by mid-band spectrum and additional mmWave spectrum (e.g. 40GHz band) may also be required.
- **Existing spectrum** is important for continuing to offer 2G, 3G and 4G services. Losing access to certain bands (e.g. 900MHz) could necessitate an operator shutting down services to part of its customer base (e.g. individuals with 2G-only devices). Over time, this spectrum can be refarmed for use by newer technologies (e.g. 5G) and will provide additional capacity to support traffic growth.

Whilst both are important, the remainder of this report focuses on the continued use of existing bands by mobile operators – and, in particular, the process adopted for renewal of mobile operators' licences at the point of expiry. We focus on the renewal of existing licences as these processes carry the greatest risks and uncertainties for operators, particularly if the loss of spectrum would mean certain customers can no longer be served. The following case studies for Norway and Thailand vividly highlight the potential risks associated with adverse outcomes from renewal processes for key spectrum bands.

[39] GSMA Intelligence, 'The Socio-Economic Benefits of Mid-Band 5G Services', February 2022.

Case Studies – Risks from spectrum renewal processes

Norway – Poor auction design leads to market exit by Tele2

Background: Tele2, the third-largest operator in Norway, held a licence for 2×5.1MHz of spectrum in the 900MHz band prior to Norway's 4G multi-band spectrum auction in 2013. Within the auction, which adopted a first price, sealed bid format, Tele2 was unsuccessful in acquiring any spectrum, which was acquired by other incumbents (Telenor & TeliaSonera) and an entrant (Telco Data).[40]

The auction design, which the regulator communicated as being driven by a desire to maximise revenues, was a one-shot first price, sealed bid auction forcing operators to make risky bids. Tele2 ultimately placed too low a bid and was left without low-frequency spectrum, which is vital for providing widespread voice and data coverage. Tele2 ultimately decided that it was unable to compete effectively in the market without this spectrum and entered into a merger agreement with TeliaSonera which was approved in October 2015, resulting in its exit from the market.[41]

Key learnings: The one-shot auction design forced operators to place risky bids on key spectrum assets and forced an existing operator to exit the market, harming the market and competition.

Thailand – New entrant outbids incumbent operator and creates 2G continuity risk

Background: In 2015, Thailand hosted a multi-band auction including a renewal of 2×20MHz in the 900MHz band, previously licensed to AIS.[42,43] There were four bidders in the auction – however, only two were successful in acquiring spectrum: True Move (the third-largest operator) and Jasmine (a new entrant). Neither of the two largest operators (AIS, dtac) acquired 900MHz spectrum, despite the spectrum being essential to AIS's (2G) network. The bidding was highly competitive – at the time, it was reported that final prices were the highest ever per MHz paid for 900MHz spectrum.[44]

Whilst it had access to other bands (1800MHz / 2.1GHz), the loss of its 900MHz spectrum created a significant business risk to AIS as it faced significant gaps in its network coverage (built on 900MHz) and had about 400,000 devices relying solely on 900MHz.[45] Ultimately, there was no impact on the market, purely as a result of Jasmine defaulting on its payments and AIS re-acquiring the 900MHz spectrum in a subsequent auction.[46]

Key learnings: By placing all of AIS's 900MHz assets up for auction, the largest operator in the market was faced with an enormous business continuity risk, placing the service of millions of customers at risk. This situation stimulated excessive bidding, driving prices beyond rational levels and resulted in one of the winning bidders defaulting on its payments.

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[40] Tele2, 'Tele2 AB: Tele2 Norway does not obtain frequencies in the Norwegian spectrum auction', 6 December 2013.

[41] Norwegian Competition Authority, 'The Norwegian Competition Authority clears the acquisition of Tele2 by TeliaSonera, subject to conditions',21 October 2015.

[42] Telegeography, 'Jasmine, True win 900MHz licences in USD4.2bn auction', 21 December 2015.

[43] Telegeography, 'NBTC confirms 900MHz, 1800MHz auction by September 2015', 17 November 2014.

[44] Developing Telecoms, 'True and Jasmine win Thai 4G licences with record bids', 22 December 2015.

[45] Telegeography, 'AIS wins month leeway to migrate 900MHz users', 17 March 2016.

[46] Telegeography, 'AIS wins uncontested 900MHz re-auction at USD2.11bn', 31 May 2016.

The prevalence of spectrum renewals in upcoming European spectrum awards

A large number of spectrum licence renewals are due in European countries over the next 10 years, as summarised in Figure 3-7 below, which covers the (European Economic Area (EEA), plus Switzerland and the United Kingdom). Specifically, Figure 3-7 outlines for each combination of country and spectrum band, the date on which existing licences (if any) are due to expire. The expiry dates are colour-coded, with expiries in the next 2, 5 and 10 years shown in red, orange and yellow, respectively. Licences which are not due to expire in the next 10 years are shown in green, whilst grey is used to denote spectrum that is yet to be awarded for mobile services in the country in question. Full details of the spectrum licences set to expire in each of the countries are provided in Annex A.

Of all the countries studied, only the United Kingdom and Liechtenstein do not have any spectrum licences expiring over this period– this is because spectrum is awarded through indefinite licences. In eight countries (Czech Republic, Estonia, Iceland, Ireland, Lithuania, Poland, Romania and Spain), all licences across all bands are set to expire within the next 10 years.

The bands which have the greatest number of expiring licences are 800MHz, 900MHz, 1800MHz, 2.1GHz and 2.6GHz. Generally, the 700MHz and 3.5GHz bands do not expire soon as they have recently been awarded for the provision of 5G services in many countries; however, there are exceptions such as in countries which have previously awarded 3.5GHz spectrum for Fixed Wireless Access use during the 2000-2010 period and these licences are now reaching their end dates.

Figure 3-7: Summary of spectrum licence expiry dates in Europe [Source: European Communications Office[47,48] and European 5G Observatory[49]]

	700 MHz FDD	800 MHz	900 MHz	1500 MHz SDL	1800 MHz	1900 MHz TDD	2.1 GHz	2.3 GHz	2.6 GHz FDD	2.6 GHz TDD	3.5 GHz	26 GHz
Austria	2044	2029	2034	2044	2034		2044		2026	2026	2039	
Belgium		2033							2027	2027	2025	
Bulgaria			2024		2024		2025		2041		2041	
Croatia	2036	2024	2024		2024	2024	2024		2024		2023	2036
Cyprus	2041	2028	2023		2023		2023		2028	2028	2041	
Czechia		2029	2024		2024	2024	2024		2029	2029	2032	
Denmark	2040	2034	2040		2032			2027	2030	2030		2025
Estonia		2030	2030		2030	2030	2030	2030	2030	2030		
Finland	2033	2033			2033				2029	2029	2033	2033
France	2035	2032	2024		2024	2022	2030		2031		2023	
Germany	2033	2025	2033	2033	2025	2025	2025		2025	2025	None	
Greece		2030	2027		2027				2030	2029	2029	
Hungary		2029	2029		2034				2029	2029	2034	
Iceland	2032	2023			2023				2032			
Ireland		2030	2030		2030	2022	2022				2032	2028
Italy	2037	2029	2029	2029	2029		2029		2029	2029	2037	2037
Latvia	2042	2033	2026	2042	2026	2030	2027	2027	2028	2028	2025	
Liechtenstein		None	None		None		None		None			
Lithuania		2030	2032		2032		2026	2029	2027	2030	2022	
Luxembourg	2035	2027	2027		2027		2033		2027		2035	
Malta		2033	2026		2026	2022	2022		2033	2033	2036	
Netherlands	2040	2029	2030	2040	2029		2040		2030	2029		
Norway	2038	2033	2033		2028	2022	2032	2022	2022	2022	2022	2022
Poland			2023		2022	2022	2022			2024		
Portugal		2027	2027		2027				2027	2027	2025	
Romania		2029	2029		2029				2029	2029		
Slovakia	2040	2028	2026		2025		2026		2028	2028	2024	
Slovenia	2036	2029	2031	2036	2031		2023		2029	2029	2022	2036
Spain		2031	2028		2030				2030	2030	2030	
Sweden		2035	2025		2027	2025	2025	2045	2023	2023	2022	
Switzerland	2035	2028	2028	2035	2028		2028		2028	2028	2035	
UK	None	None	None	None	None	None	None	None	None	None	None	

The relevance of spectrum renewals to mobile operators

As highlighted above, there are several key bands due for renewal in many countries:

- The 800MHz and 2.6GHz bands were made available for 4G services and continue to be important for capacity provision (and in the case of the 800MHz band, coverage of 4G deep indoors and in less populated areas).
- The 900MHz band is key for the continuing provision of 2G services (and in some cases also for the continuation of 3G services). Over time the spectrum is expected to be refarmed for 4G and 5G.
- The 1800MHz band was once key for providing additional 2G capacity (and in some countries some of this band continues to be used for 2G) however the spectrum has increasingly been refarmed for 4G since 2012.
- The 2.1GHz band was the key pioneer band for 3G but the spectrum has frequently been refarmed for use for 4G and 5G services.

It can be seen that these spectrum bands are all key components of a mobile operators' overall spectrum portfolio.

The lack of availability of spectrum in any particular band could have a major impact on mobile operators. For example, lacking access to 900MHz spectrum could mean an operator cannot offer nationwide mobile services – this would not just impact users of 2G/3G-only devices, but also users of 4G devices that are not VoLTE capable. A further example is loss of the 800MHz band, which would mean that nationwide 4G coverage would be lost. The loss of 1800MHz, 2.1GHz and 2.6GHz spectrum would result in a loss of 4G (and sometimes 2G and 3G) network capacity. Loss of a combination of bands would be even more disastrous for a mobile operator. We present two case studies demonstrating the impact that the loss of spectrum can have on operators.

Fundamentally, because continued access to existing spectrum is so critical to operators, a lack of information about how expiring spectrum licences will be re-assigned and the price that will need to be paid to maintain access to spectrum creates a huge amount of uncertainty/risk for an operator:

- It is not clear whether the operator will maintain access to any individual spectrum band and therefore this may require a major reconfiguration of the network and/or the loss of customers – thereby impacting on the revenues and profitability of the business and the cash remaining (if any) for investment in network expansion. Consequently, making large investments in network expansion is incompatible with operators waiting to undertake renewal processes for their existing spectrum.
- If the operator ultimately needs to pay a high price for the spectrum, that will limit the amount of funding available for network investments – including deploying new base station sites for coverage expansion. So funds cannot be invested in advance of the renewal process just in case they are needed to reacquire existing spectrum holdings.
- In the last few years of the existing spectrum licence, operators will be reluctant to invest in new technologies using the spectrum in question since there is always a risk that they may not be able to reacquire the spectrum – essentially this creates a 'dead' period towards the end of licences when investment in the relevant spectrum band(s) ceases.

[47] European Communications Office, 'ECO Report 03: The Licensing of "Mobile Bands" in CEPT', 9 March 2022.

[48] European Communications Office, 'ECO Report 03: The Licensing of "Mobile Bands" in CEPT', 6 April 2021.

[49] European 5G Observatory, 'Belgium grants provisional 5G licences in the 3.5GHz band', 15 May 2020.

For all the above reasons, it is important for mobile operators to have confidence that spectrum renewal processes will enable them to retain key spectrum bands at a reasonable price so that they can divert their energy and investments into deploying 5G and enhancing mobile network coverage, thus helping to achieve the European Digital Decade and European Green Deal targets/vision. In the following sections of this report we discuss how policymakers can help to provide mobile operators with this level of confidence.

4. Best practices for spectrum pricing

One of the key contributions to mobile operators' record investments is spectrum acquisition, as alluded to in Section 3.3. Given this, and the fact that spectrum availability and pricing are often under the direct control of regulators, it is an area in which regulators can make a positive contribution towards easing operators' financial challenges. By easing the financial burden of spectrum acquisition, regulators can increase the investment operators are able to make in other areas (e.g. 5G deployment), reduce the investment gap, and thereby increase the likelihood of Digital Decade and European Green Deal targets being met.

If one is to lessen the financial burden of acquiring spectrum, it is essential to firstly understand the Total Cost of Spectrum Ownership (Section 4.1). Furthermore, it is essential to understand the risks and impacts of high spectrum prices and adopt best practice approaches to spectrum pricing (Section 4.2). Ultimately, mobile operators are having to acquire additional spectrum to support high traffic growth at a time when revenues are static or declining – therefore, if spectrum were to continue to be awarded at the same unit price (per MHz), the overall spectrum cost (as a proportion of revenue) would increase. This is unsustainable and therefore the unit price of spectrum must decrease.

This applies to all spectrum, including existing spectrum which is set to expire, and is therefore particularly relevant in the context of upcoming spectrum renewals, the importance and prevalence of which we highlighted within Section 3.3.

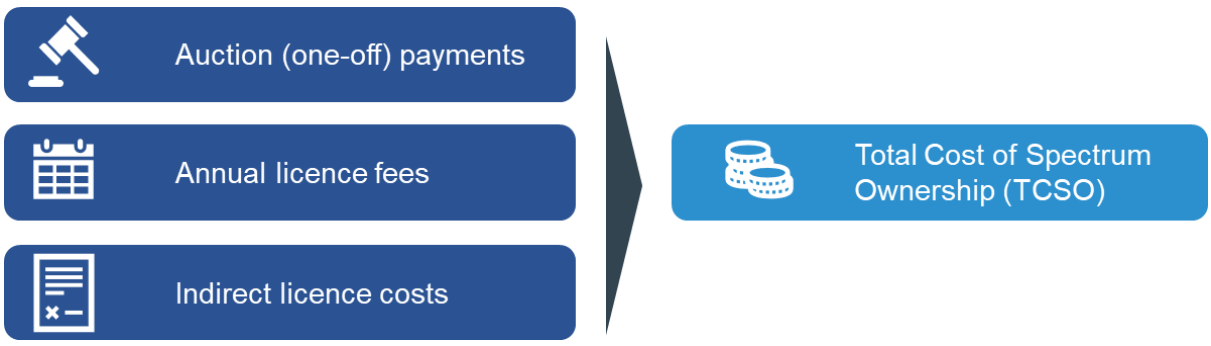
4.1 Total cost of spectrum ownership

We highlighted in Section 3.3 that operators require a portfolio of low-, mid- and high-band spectrum to support high-speeds to customers, provide sufficient network capacity and enable network coverage to be provided to less populated areas in the most cost-effective way. In light of this, operators will require both new spectrum and continued access to existing spectrum in order to be able to offer a complete set of mobile services (2G, 3G, 4G & 5G).

However, the financial burden of spectrum acquisition is a key component of the financial challenges facing operators. Furthermore, the availability and price of spectrum are often under the direct control of regulators, in contrast to many of the other sources of financial pressure outlined above (e.g. revenue decline). Spectrum pricing is therefore an area in which regulators can make a positive contribution towards easing operators' financial challenges, as highlighted above.

For regulators to make positive decisions regarding spectrum pricing, it is important to consider all aspects of spectrum price; the Total Cost of Spectrum Ownership comprises several components:

Figure 4-1: Components of the Total Cost of Spectrum Ownership



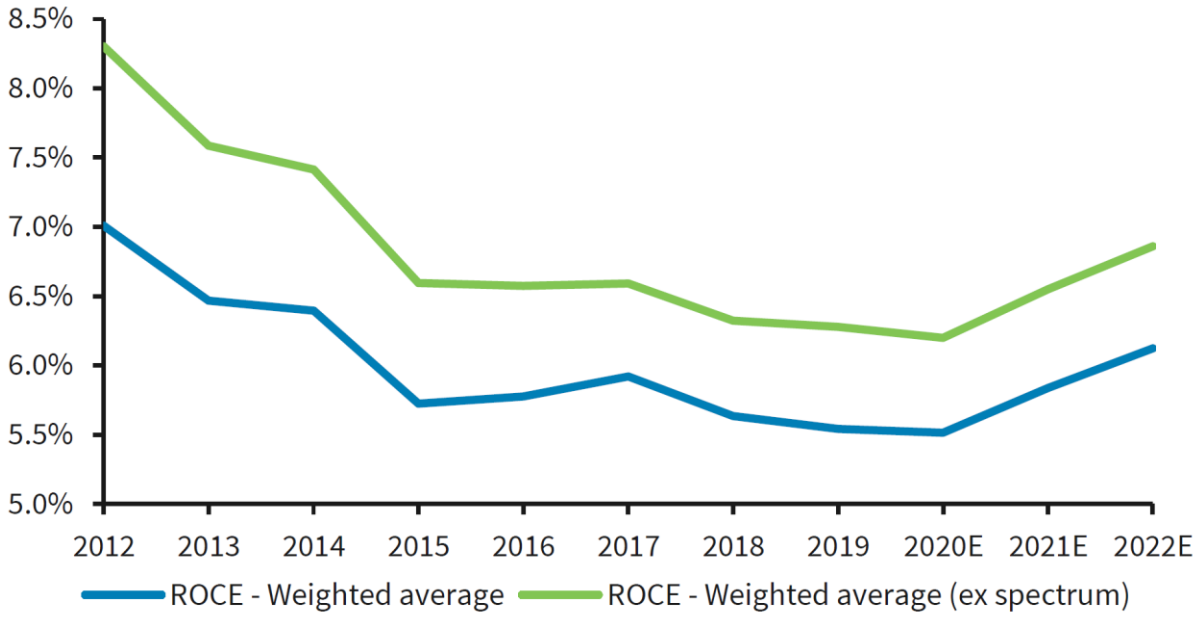
- **Auction (one-off) payments**: The amount of money determined by the award process, typically expressed as a one-off lump sum (although staggered payments are increasingly common).
- **Annual licence fees**: Annual spectrum fees are charged to cover the cost of administering the spectrum and are typically determined outside the award process.
- **Indirect licence costs:** Licences can contain specific obligations, for example to extend network coverage. The costs of these obligations can be difficult to quantify as they depend on the operators' private cost structures and network rollout ambitions; however, they can be significant.

The total cost of spectrum to a mobile operator is the sum of the three components. Therefore, a mobile operator will only seek to acquire spectrum if the TCSO is lower than the value of the spectrum to the mobile operator (e.g. in terms of network cost savings, additional revenue-generating opportunities etc).

Consequently, the true 'reserve price' in an auction is essentially the sum of the published reserve price, annual licence fees and any indirect licence costs. Again, if this sum is higher than the value of the spectrum to the operator, then the operator will not be interested in acquiring the spectrum in an auction, no matter how low the published 'reserve price' appears to be. Therefore, policymakers must consider the cost of annual fees and licence obligations when determining auction reserve prices – if the cost of one component is high (e.g. a coverage obligation), the others should be reduced to account for this.

Unsurprisingly, given the importance of spectrum to mobile operators, the amount of operator expenditure on spectrum is considerable. One way to assess its relative magnitude is to consider the impact of spectrum expenditure on operator returns. As shown in Figure 4-2, analysis by Barclays Research suggests that expenditure on spectrum has reduced the capital returns of European mobile operators by around 20% – from a level which is already below the cost of capital (estimated at 7%) and is therefore already unsustainable in the long-term.

Figure 4-2: EU telecoms operators Return on Capital Employed (ROCE) including and excluding spectrum [Source: Barclays Research[50]]



Another way to evaluate the impact of spectrum costs on mobile operators is to consider these costs as a percentage of revenues. Here, the cost of spectrum considers all mobile spectrum licences

[50] Barclays Research, 'European Telecom Services. The New Normal', June 2020.

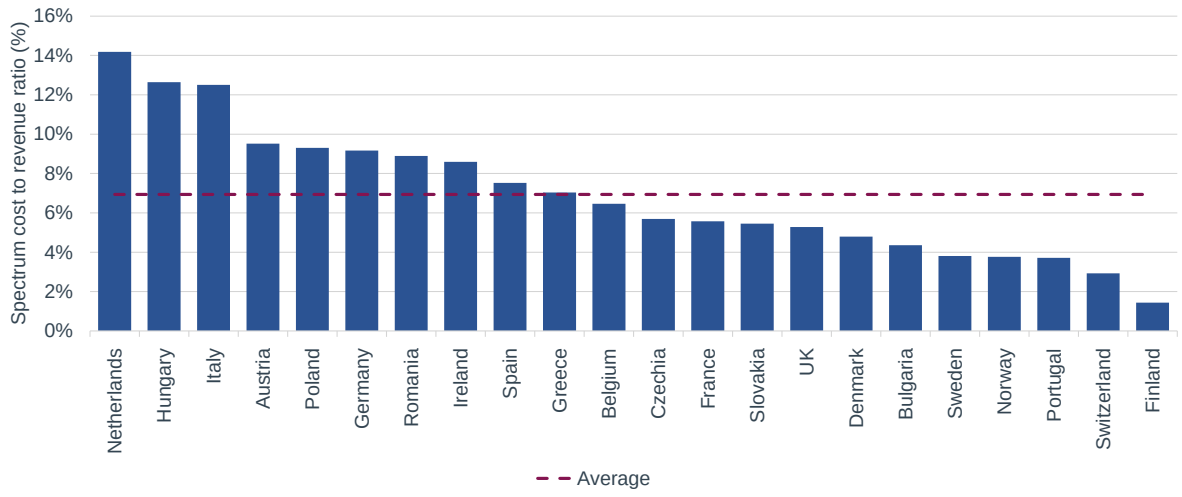
currently in use by the operator, not just those most recently awarded. It considers both upfront payments (translated into an annualised amount) and any annual fees associated with each licence. The resulting annualised spectrum cost for each operator can then be divided by the operator's annual mobile service revenue. A similar calculation can be undertaken at a country level by summing the spectrum costs of all of the operators and dividing by the total mobile service revenues in the country.

We have analysed spectrum costs as a proportion of revenue in 22 European countries, with the results summarised in Figure 4-3 below. This illustrates two key points.

Firstly, spectrum costs are a significant burden for operators, representing an average of ~7% of mobile service revenue. Given that the average capital intensity of European mobile operators was estimated at ~18% by ETNO[51] (details provided within Section 3.2), spectrum costs are estimated to represent an average of ~35-40% of capital expenditure. This is a very significant proportion.

Secondly, there is variation in spectrum costs between countries, with the highest costs observed in the Netherlands and the lowest in Finland. We examine the underlying reasons further in Section 5.2 – however, the fundamental difference between these countries is that Finland has adopted simple auctions aiming to guarantee spectrum access for all operators, whilst the Netherlands has adopted complex auctions designed to promote competition (including poorly designed spectrum reservations). We consider the relationship between spectrum costs and consumer outcomes, both in terms of network quality/availability and service pricing, in Section 4.2 – multiple studies have established relationships between high spectrum prices and unfavourable consumer outcomes.

Figure 4-3: Spectrum cost to revenue ratio [Source: Aetha]



The main limitation of this calculation is that it does not take account of indirect licence costs (e.g. coverage obligations) since these are hard to quantify; however it does provide a lower-bound indication of the impact of spectrum costs on the mobile operators/all mobile operators in the country.

The spectrum costs considered in Figure 4-3 above include costs for both new and existing spectrum and are typically directly linked with the quantity of spectrum licensed to operators, with fees also varying depending on frequency and device availability etc. Spectrum is a pre-requisite for the provision of mobile services – operators cannot exist without it – and therefore the fees associated with it can, to some extent, be considered to be an additional form of taxation on the industry – a 'spectrum tax'.

[51] ETNO, 'State of Digital Communications 2022', February 2022.

This is particularly true of ongoing spectrum costs; specifically, annual licence fees and one-off fees for previously assigned spectrum, such as that available in renewal processes. This spectrum is required for continuity of services and, over time, will be refarmed to the latest more spectrally efficient technologies; however, the spectrum on its own does not directly enable the provision of all new products/services or open up new revenue streams. Therefore any costs associated with this spectrum may reasonably be considered to be a form of additional taxation on mobile operators.

4.2 Risk and impact of high spectrum prices

In this section, we discuss the risks and impacts of high spectrum prices. As discussed in Section 3.3, mobile operators are having to acquire new spectrum bands as well as renew their existing spectrum holdings in order to provide services to customers and support the high traffic growth levels (typically 30%-50% network traffic growth each year). At the same time, revenues are relatively static or declining. Therefore, if spectrum were to continue to be awarded at the same unit price (per MHz), the overall spectrum cost (as a proportion of operator revenues) would increase considerably.

Such a situation would be unsustainable – as shown in Section 4.1, the return on capital employed for European operators is already below the cost of capital. Effectively, as the amount of spectrum held by an operator increases, the unit price paid by the operator for spectrum has to decrease. However, in setting prices for spectrum (including reserve prices for auctions), regulators often use the outcomes of historic auctions in the country as a basis for setting spectrum prices. This is likely to result in excessive spectrum prices being set, carrying significant risks (including the risk of spectrum remaining unassigned).

There are many examples of spectrum going unassigned in auctions as a result of the effective reserve prices being set too high. This can arise from different components of the TCSO – not just the reserve price for the auction itself. For example:

- High annual fees have resulted in spectrum remaining unassigned in Romania and Mexico
- An onerous emergency services obligation resulted in spectrum remaining unassigned in the USA
- High auction reserve prices in India and Thailand have resulted in spectrum remaining unassigned.

In all cases, the failure to assign spectrum is indicative of regulators failing to recognise (i) the need for unit spectrum prices to reduce over time in order for the telecoms industry to be sustainable, and (ii) the need to consider all aspects of the TCSO (auction payments, annual licence fees and indirect licence costs) when setting auction reserve prices.

To address this issue and ensure that spectrum prices remain affordable for operators in the long term, it is essential for policymakers to consider all components of the TCSO across operators' entire spectrum portfolio when renewing spectrum. The overall objective should be to ensure that the spectrum tax (i.e. TCSO as a proportion of revenue) is set at a manageable level – it certainly should not exceed 10%, and the overall benefits to the economy are likely to be higher if it is at a lower level. Only by keeping the spectrum tax at a manageable level is it possible to avoid the problems highlighted in the case studies below.

Case studies – The negative impact of annual fees on spectrum auctions

Romania – High annual fees leading repeatedly to unsold spectrum

Background: 2.6GHz FDD spectrum has remained unassigned in Romania through two auction processes (2012 and 2021) due to very high reserve prices.[52,53,54] In the 2012 auction, spectrum also remained unassigned in the 800MHz band for the same reason.[55] This has been primarily due to high annual fees, resulting in the TCSO being in excess of operators' valuations.

Key learnings: The ultimate impact of this has been spectrum remaining unassigned for many years, denying both operators and consumers from the potential benefits associated with it. This is clearly an inefficient outcome and could be solved easily be reducing annual spectrum fees.

Mexico – High annual fees leading to spectrum being unassigned and even returned

Background: Large amounts of AWS and PCS spectrum remain unassigned in Mexico. As an example, in the 2021 auction for 800MHz, AWS, PCS and 2.5GHz spectrum, only 3 of the 41 lots were sold. The result was attributed to high annual fees by the regulator, IFT, which has previously submitted proposals for adjusted annual licence fees to the Mexican government. [56]

Mexican operators have even returned spectrum due to the high annual spectrum fees. Telefónica relinquished its 800MHz, PCS and 2.5GHz frequencies, reportedly generating USD104 million in savings. Having returned its spectrum, it now provides services as a virtual operator using AT&T's network, having signed an access agreement with AT&T in 2019.[57]

Key learnings: High annual fees have left large amounts of spectrum unsold and have forced an operator to shut down its network. This is an inefficient outcome which is widely accepted to have negatively impacted consumers through reduced quality of service etc.

[52] ANCOM, 'Results of the spectrum auction for mobile electronic communications', 24 September 2014.

[53] ANCOM, 'Task book for the organisation of the competitive selection procedure in view of granting some radio frequency right in 800MHz, 2600MHz and 3400-3600MHz', September 2021.

[54] ANCOM, 'This year's auction for spectrum allocation has been completed', 23 November 2021.

[55] GSMA, 'Effective Spectrum Pricing in Europe: Policies to support better quality and more affordable mobile services, September 2017.

[56] Telecoms.com, 'Mexican regulator blames high prices for spectrum auction failure', 8 October 2021.

[57] Telegeography, 'Telefonica generates EUR95m from returned Mexican spectrum, report says', 28 February 2020.

Case studies – The impact of high reserve prices and costly obligations on auctions

Thailand – Historic spectrum pricing leads to unsold spectrum

Background: As previously highlighted, the 2015 Thai 900/1800MHz auction resulted in Jasmine (a new entrant) defaulting on its payment. but contributing to competitive bidding leading to very high prices.[58] In 2018, a further auction for 1800MHz only sold two of the nine available lots.[59] The primary reason for this were the reserve prices, set based on prices from the 2015 auction.[60]

Key learnings: With more spectrum available in the market, there was no interest in acquiring spectrum at high prices. By setting the wrong reserve price, the regulator contributed to there being unsold spectrum – a situation that was repeated in an auction of 850MHz spectrum in 2018.[61]

India – High reserve prices lead to unsold spectrum

Background: India has repeatedly failed to assign spectrum, including in the 700MHz band, due to the setting of very high reserve prices.[62] It first attempted to award spectrum in the 700MHz band in 2016; however, all spectrum remained unassigned.[63] In total, more than 50% of the available spectrum in this auction (which included other bands) remained unsold. A second auction was held in 2021; however, all 700MHz spectrum again remained unassigned, as well as spectrum in the 2.1GHz and 2.5GHz bands (in total, ~70% of the available spectrum remained unassigned in 2021).

Key learnings: The primary reason for spectrum remaining unassigned has been high reserve prices, combined with the heavy debt burden on the industry resulting from previous high-price auctions. The result is that large quantities of spectrum remain unassigned, despite operators expressing clear interest, holding back 4G deployments and impacting the quality of service.

USA – Emergency service obligation leads to unsold spectrum

Background: The 2008 700MHz auction included one 2×5MHz lot (D Block) requiring the winning bidder to deploy a national public safety communications network via a public/private partnership. As all bids received in the auction did not exceed the reserve price, the lot remained unsold. [64]

Key learnings: This is an example of where onerous licence obligations (a key element of the TCSO) resulted in spectrum remaining unassigned – bidders considered that the cost of addressing this obligation made acquiring it at the specified reserve price unjustifiable.

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[58] Mobile World Live, 'Thailand's AIS, True pay $1.1B each to win 1.8GHz licences', 13 November 2015.

[59] Telegeography, 'NBTC's 1800MHz auction concludes with just two blocks sold', 20 August 2018.

[60] NERA Economic Consulting, 'Spectrum Auction Risks Leaving Thailand Stranded in a Mobile Data Slow Lane', 15 December 2017.

[61] Telegeography, 'AIS, DTAC submit bids for 1800MHz spectrum; 850MHz auction cancelled', 9 August 2018.

[62] European 5G Observatory, 'Spectrum auction raised 778 billion INR (9 billion EUR) in India, but 700MHz spectrum was left unsold for second time', 18 March 2021.

[63] Telegeography, 'Spectrum auction nets USD9.9bn despite conservative bidding', 7 October 2016.

[64] FCC, 'Auction 73: 700MHz Band', 18 March 2008.

Even in cases where the reserve prices in an auction have not been so high that the spectrum remained unassigned, high prices are unlikely to represent an efficient market outcome and can be considered to be a revenue (tax) raising exercise for the government, as illustrated in the case study for Italy below.

Case study: Italy – Spectrum packaging resulting in high prices

Background: Italy assigned 200MHz of 3.5GHz spectrum in 2018. The auction was successful in terms of assigning spectrum; however, operators were forced to compete strongly for the spectrum, resulting in prices much higher than in other European countries.[65] There were two main reasons:

- Firstly, a relatively small quantity of spectrum was made available. 200MHz equates to 50MHz per operator in Italy, far below the 80-100MHz that operators typically target.
- Secondly, rather than awarding the spectrum in equal-sized lots which would allow all operators to acquire a meaningful quantity, the band was split into two 80MHz lots and two 20MHz lots. This meant that at least two operators would acquire 40MHz or less, effectively forcing an outcome that would create 'winners' (those acquiring ≥80MHz) and 'losers' (those acquiring ≤40MHz).

Key learnings: The high prices in this auction are likely to have negatively impacted upon 5G deployment in Italy, as a greater proportion of operators' budgets had to be diverted towards spectrum acquisition and away from network investment. Therefore, it could be argued that this auction failed to meet its objectives, despite the successful assignment of all spectrum.

A study undertaken by NERA[66] on a possible link between spectrum fees and service prices also examined whether there could be a link between spectrum fees and network investment. This study considered network investment in terms of the coverage of 3G and 4G networks, average speeds and the proportion of subscribers on 4G networks, finding a modest correlation between higher prices for spectrum and lower levels of network investment. The results of this study were referenced within the GSMA's report on 'effective spectrum pricing'.[67]

A report produced by LS telcom, PolicyTracker and VVA for the Directorate General for Communications Networks, Content and Technology of the EC[68] included an analysis of the relationship between auction prices and network coverage, comparing OpenSignal data on 4G availability with auction prices. The results suggested that there may be an inverse relationship between price paid for spectrum and network availability (i.e. higher auction prices are associated with lower 4G availability).

One counter-argument that is sometimes made regarding the impact of high spectrum prices (particularly from competitive auction processes) on network investment is that the intensity of competition in the auction resulting in high auction prices will translate into operators maximising their network investments in order to secure the high returns that are required to justify the prices paid for the spectrum. In considering this issue, it is important to consider the different types of investments that are made:

- Investments that are made for commercial reasons i.e. to help maximise an operator's revenues and profit – such as the rapid deployment of 5G in the biggest cities. Here it is possible that this

[65] European 5G Observatory, 'Italian 5G spectrum auction', 15 October 2018.

[66] NERA Economic Consulting, 'The Impact of High Spectrum Costs on Mobile Network Investment and Consumer Prices', May 2017.

[67] GSMA, 'Effective Spectrum Pricing: Supporting better quality and more affordable mobile services', February 2017.

[68] LS telcom, VVA and PolicyTracker for the European Commission Directorate General for Communication Networks, Content and Technology, 'Study on Spectrum Assignment in the European Union', October 2017.

argument may apply although it would be expected that the operator's business case would include the profit-maximising investment/network deployment strategy, independently of the amount paid for spectrum.

- Investments that are made for wider societal reasons e.g. extending network coverage that on a strict commercial basis are uneconomic for the operator to provide coverage. This is the type of network investment that we are discussing in this report and clearly if an operator is forced to spend more money on spectrum, less money will inevitably be available for such network coverage expansion.

A further argument is that network investment can in some cases be seen to increase in cases where operators have not acquired spectrum due to high prices or acquired less spectrum that they would have targeted in advance of an auction. Here it is important to distinguish between efficient network investment and inefficient network investment. Specifically if an operator does not acquire spectrum in an auction, it may actually be forced to spend more money on its network in order to deploy new network sites to support the levels of traffic generated by the operator's customers. However this is not efficient investment – the more efficient investment would be to deploy additional equipment on existing sites to use new frequency bands as this would be considerably lower cost than deploying new sites. In this report we are concerned with maximising efficient investments by network operators – not inefficient investments.

On the topic of the link between high spectrum prices and the prices of mobile services to consumers, in a competitive market with high fixed costs/barriers to entry such as telecoms, market prices typically seek to recover marginal costs and fixed costs[69]. Consequently, if the costs of inputs such as spectrum, site rental, staff salaries etc are higher, then ultimately market prices will reflect these higher costs since they need to be recovered by the operator. Consequently if spectrum fees are higher, then over time, the underlying price of mobile services will also be higher - and if spectrum fees are lower, then the underlying price of mobile service should be lower.

In summary, high spectrum prices can have a detrimental effect on network investment. With the increasing amount of spectrum required by operators to meet customer needs, unit prices for spectrum must go down. Therefore, regulators should not continue to adopt the approach of using previous auction price outcomes to set reserve prices for upcoming auctions – otherwise, these auctions are going to result in spectrum remaining unassigned with hugely detrimental impacts on the operation of the mobile market, the prices of mobile services and levels of network investment by mobile operators. Instead, spectrum prices should be set in consideration of all components of the TCSO, with the overall objective of keeping the spectrum tax at a manageable level (<10%).

[69] See, for example, Harald Gruber, 'The Economics of Mobile Telecommunications', 2005.

5. Best practices for spectrum renewal processes

Spectrum renewal processes can pose a significant business risk to mobile operators, especially if (a large share of) their key spectrum holdings are awarded through a single process. However, policymakers can contribute significantly to minimising any unnecessary risks from the award process.

In this section, we briefly discuss the key questions that policymakers need to address when developing their approach to the renewal of existing spectrum licences (Section 5.1) before presenting our recommendations based on international best practices (Section 5.2). These recommendations are made in the context of ensuring that the TCSO is manageable for mobile operators. Finally, we detail the benefits of renewing spectrum in line with our best practice recommendations (Section 5.3).

5.1 Key questions facing policymakers

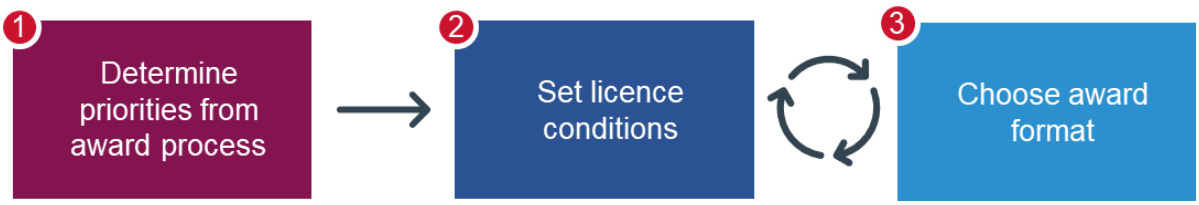
Developing a best practice spectrum award remains a challenging task, despite the large number of awards that have taken place in Europe over the last 10 – 20 years. An ever-changing technology environment, a growing number of available bands and changing market structures all contribute to there not being a 'one-size-fits-all' solution. This is particularly true for spectrum renewals.

The first question to consider when awarding spectrum is that of **timing**. The appropriate timing of renewal processes will vary; however, it is important that renewal occurs in a timely manner so as to minimise the uncertainty faced by operators.

Once the appropriate timing of the renewal process has been determined, there are three key questions that policymakers should answer when awarding spectrum – as illustrated in Figure 5-1 below:

1. ***What are the priorities from the renewal process?*** Without a clear target to achieve, it is impossible to design the right process.
2. ***Which licence conditions to attach to spectrum?*** Licence conditions cover a wide range of topics (technology restrictions, coverage obligations, licence duration etc.) and have a significant impact on the value of the spectrum that is awarded. Therefore, they need to be carefully defined.
3. ***Which type of award process is most suitable?*** Whilst auctions are the most common format, there are a variety of award mechanisms available to policymakers to award spectrum.

Figure 5-1: Key questions facing policymakers ahead of spectrum awards



In the remainder of this section, we discuss these key questions in more detail, noting that the choice of award process can be an iterative process, interlinked with the choice of licence conditions. In each case, we also outline our recommendations, based on international best practice. With respect to the question of setting the right licence conditions, we focus in particular on the question of licence duration.

5.2 Recommended best practice approach to spectrum renewal

In this section, we outline our recommendations for conducting award processes for previously assigned spectrum based on international best practices. We do so in the context of the key questions highlighted within Section 5.1. Specifically, we provide detailed recommendations and examples of good/bad practice with regards to the following:

- **Timing of renewal process** (Section 5.2.1): Renewal processes should be commenced well in advance of licence expiry to limit the uncertainty faced by operators and thereby protect investor confidence.
- **Objectives of process** (Section 5.2.2): The objectives of the spectrum renewal process and relative priorities should be clearly defined prior to its commencement.
- **Conditions of spectrum use** (Section 5.2.3):
  - **Longer licence durations:** Longer, ideally indefinite, licence durations provide certainty for operators when making network investments, as well as allowing a longer amortisation period.
- **Design of award process** (Section 5.2.4):
  - **Administrative licence renewal:** Administrative licence renewal processes may be appropriate in cases where demand does not outstrip supply.
  - **Auction:** Auctions are likely to be appropriate where demand for spectrum exceeds supply.
  - **Partial renewal:** Where demand for spectrum exceeds supply but existing licensees face business continuity risks if they lose spectrum, policymakers should consider guaranteeing renewal for part of operators' holdings in key bands, thereby reducing the uncertainty.
- **Auction best practices** (Section 5.2.5)**:** To be adopted in situations where an auction is necessary.

5.2.1 Timing of renewal process

Naturally, operators are happy to invest in recently acquired spectrum, granted that it can be used for a period of at least 10 – 20 years. However, once the licence expiry approaches, uncertainty increases and so does investment hesitancy. If the expiring spectrum were not to be renewed, the scope to recover investment prior to the licence expiry would reduce significantly, meaning there is a greatly increased financial risk. This can be particularly damaging if the licence expiry coincides with a period of renewed investment, as is currently the case in Europe, where operators are considering significant investments in 5G but also face renewal decisions on key spectrum assets, as shown in Section 3.3.

It is therefore imperative that renewal processes are commenced well in advance of licence expiry, limiting the degree of uncertainty faced by operators and protecting investor confidence. This recommendation is supported by:

- Article 45[70] of the European Electronic Communications Code (EECC) which states that *"[Member States shall …. by] (c) ensuring predictability and consistency in the granting, renewal, amendment, restriction and withdrawal of rights of use for radio spectrum in order to protect long-term investments"*.

[70] Article 45 of European Union, 'Directive (EU) 2018/1972 of the European Parliament and of the Council of 11 December 2018 establishing the European Electronic Communications Code', 17 December 2018.

- Article 50[71] of the EECC which states that *"National regulatory or other competent authorities shall take a decision on the renewal of individual rights of use for harmonised radio spectrum in a timely manner before the duration of those rights expired"*.

The optimum timing is situation-dependent; however, it is advisable for renewal to be completed at least 1-2 years prior to licence expiry. This has a secondary benefit of allowing operators to plan for any spectrum redistribution or other changes to licence terms that are deemed necessary during the renewal process.

Positive examples in this context are provided by the regulatory authorities in Germany[72] and Croatia – with key spectrum assets expiring around 2024/2025, the regulators in both countries are already engaging proactively with industry on the best models for renewals, with award processes planned at least 2 years prior to the expiry of the spectrum licences.

5.2.2 Objectives of process

As for all spectrum award processes, the first step for policymakers is to determine their main objective(s) for the renewal. In all cases, it is essential for the objectives and priorities of the process to be well understood prior to the commencement of the renewal process – this information is required in order to make informed decisions regarding other aspects of the renewal process (e.g. award format, licence conditions).

The objectives of the renewal process will vary depending on the situation, but commonly include:

- Creating incentives to ensure the technically and economically efficient use of spectrum
- Encouraging investment in the widespread deployment of innovative new technologies and services
- Ensuring that the award process is transparent and non-discriminatory, allowing fair access to spectrum for all relevant parties
- Protecting competition in the mobile market, both at the retail and infrastructure level
- Ensuring a fair return for a valuable public resource
- Maximising the quality of mobile services received by consumers, both in terms of network speeds and coverage
- Minimising retail prices for mobile services (or, more directly, avoiding inflated retail prices due to high spectrum prices).

In best practice spectrum award processes, we would expect the regulator's priorities to include encouraging the growth and development of the mobile market, (including expanding network coverage), maintaining (or increasing) competition between operators, and encouraging investment and innovation. These priorities are aligned with the provisions of the EECC, whose objectives[73] include:

- Promoting connectivity and access to, and take-up of, VHCNs
- Promoting competition and efficient investment
- Contributing to the development of the internal market
- Promoting the interests of the citizens of the Union.

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[71] Article 50 of European Union, 'Directive (EU) 2018/1972 of the European Parliament and of the Council of 11 December 2018 establishing the European Electronic Communications Code', 17 December 2018.

[72] German regulator Bundesnetzagentur has already launched three consultation processes to prepare for the expiry of 800MHz, 1800MHz and 2600MHz spectrum by the end of 2025, the 'Frequenzkompass 2020', the 'Szenarienpapier 2021' and the 'Orientierungspunkte 2022'.

[73] See Paragraph 23 of European Union, 'Directive (EU) 2018/1972 of the European Parliament and of the Council of 11 December 2018 establishing the European Electronic Communications Code', 17 December 2018.

More specifically, Article 45(2) of the EECC requires members states to act by "ensuring predictability and consistency in the granting, renewal, amendment, restriction and withdrawal of rights of use for radio spectrum in order to promote long-term investments".

Conversely, we would not expect maximising spectrum assignment revenues to be a priority – Best Practice 24 of the European Connectivity Toolbox[74] specifically states that "Member States should avoid revenue maximization". Although we understand that there is sometimes pressure from government to secure a minimum amount of revenue – we would expect the regulator to prioritise the long-term economic benefits of having a functioning mobile market and maximising service availability/connectivity over short-term government revenues. Best Practice 29 of the European Connectivity Toolbox further encourages Member States to consider the use of financial incentives (including discounts on spectrum prices) in combination with coverage obligations. As an example of the implementation of this, Denmark now allows licensees to postpone payments for spectrum licences until after the time that coverage commitments have been fulfilled[75].

We also note that improved connectivity has the potential to elicit significant economic benefits, increasing the productivity and profitability of businesses across many industries. This is likely to translate into increased tax revenues for governments – therefore, lower spectrum fees may, in the long-term, translate into increased government revenue.

5.2.3 Conditions of spectrum use

A key question is how which licence conditions to attach to the spectrum. As highlighted in Section 5.1, licence conditions cover a wide range of topics (technology restrictions, coverage obligations, licence duration etc.) and have a significant impact on the value of the spectrum that is awarded, meaning they need to be carefully defined when renewing spectrum. The most significant consideration when renewing spectrum is the duration of new/renewed licences and, therefore, we focus on this issue here. However, all licence conditions must be carefully considered for successful renewal to be achieved.

Longer licence durations

Regulators can sometimes be tempted to offer short 'extensions' to existing licences (e.g. an additional 5 years), particularly in cases where the renewal process is administrative rather than competitive. However, this does little to address the uncertainty faced by operators with regards to spectrum renewal, potentially damaging investment.

As for newly assigned spectrum, it is important that licence durations are sufficiently long to encourage investment – specifically, operators investing in the deployment of new radios and antennas for a particular frequency band will require time to recover this investment and a longer amortisation period can enhance an operator's balance sheet. A 5-year licence does not provide sufficient time to do so and, therefore, such a short period should not be used unless there are particularly strong spectrum management reasons why it is appropriate (e.g. to align expiry with other licences in the band).

However, even with longer licence durations, one of the main issues with a finite duration licence is that it creates a 'dead period' at the end of the licence where no network investment is likely to take place (unless there is a very high likelihood of renewal). These 'dead periods' arise due to the uncertainty for operators over whether they will regain access to the spectrum following licence expiry, especially if a competitive award process is likely. This risk means that little investment in using the spectrum (e.g.

[74] European Union Connectivity Special Group, 'Common Union Toolbox for Connectivity', March 2021.

[75] See 'Connectivity Toolbox: Implementation Report of Denmark', published by the European Commission on 19 May 2022.

deploying a new technology) is made towards the end of its licence period – this is not the most efficient use of spectrum that regulators aim for.

Indefinite spectrum licences overcome this problem. Few countries have adopted such an approach – mainly the USA (even in the USA, licensees are subject to "substantial service" requirements). The UK has also adopted perpetual licences for certain mobile frequency bands where spectrum has been auctioned with an initial minimum term (typically 20 years) for which a fixed price is paid, after which licences are renewed annually. Japan is another example of a country making use of indefinite spectrum licences. We provide further details of these examples in the case studies below.

Case studies – Countries providing long-term spectrum certainty

USA – Initial term with indefinite extension

Background: The American regulator, the FCC, has awarded renewable spectrum licences in many bands, including PCS, WCS, 700MHz, AWS and 3.5GHz.[76,77] Licences are awarded with an initial term which is typically either 10 or 15 years. However, there is a presumption of renewal, other than in exceptional circumstances.

Key learnings: This right of renewal means the spectrum licences are effectively of indefinite duration, providing operators with greater certainty regarding their future spectrum holdings and thereby promoting investment.

UK – Initial term with indefinite extension

Background: For certain frequency bands, the United Kingdom regulator, Ofcom, has awarded spectrum licences of indefinite length with a fixed initial licence period during which the licence cannot be revoked other than in exceptional circumstances (e.g. if the terms of the licence have been breached). For example, in the UK's multi-band spectrum auction in 2021, all licences were awarded with an initial term of 20 years. After this initial term, the licences are renewed annually on payment of the annual licence fee, however Ofcom has the right to revoke the licence for spectrum management reasons, provided it gives operators at least five years' notice.[78] Essentially the licences effectively become indefinite in duration. The same indefinite licence durations apply in other spectrum bands, including the 800MHz, 2.1GHz and 2.6GHz bands etc.[79]

Key learnings: Awarding licences of indefinite duration provides operators with greater certainty regarding their future spectrum holdings and thereby promotes investment. Ofcom does however face the challenge of setting the appropriate annual fee for the spectrum after the initial minimum term is over.

Japan – Base-station licences with indefinite renewal option

Background: In the 2019 5G award already discussed above, the award conditions did not specify a specific licence duration as spectrum licences are granted for individual base stations with a duration of 5 years.[80] However, as these licences are renewable, they effectively become indefinite in duration.

Key learnings: Whilst this approach raises concerns in terms of its complexity, it provides more certainty regarding future spectrum availability, encouraging investment.

A further benefit of indefinite licences is that they increase liquidity by promoting spectrum trading. There is extensive spectrum trading in the USA, partially for historical reasons due to the award of licences on a localised basis but also because of the inherent value of indefinite use of the asset. The UK is the

[76] FCC, 'Report and Order – Promoting Investment in the 3550-3700MHz Band', 24 October 2018.

only European market where any major mobile spectrum trades have taken place and these trades of 1400MHz and 2.6GHz spectrum may not have occurred if the licence durations had been fixed.

Case study: Spectrum trading in the UK and USA

Background: One potential impact of indefinite licences is in spectrum trading – i.e. the market migrating spectrum to the party which can make most efficient use of it, without the direct involvement of regulators. It has been allowed in many countries for a number of years; however, there are relatively few examples of successful spectrum trades. The UK and USA buck this trend. For example, the UK has seen trades in the 1400MHz (Qualcomm to Vodafone/Three)[81] and 2.6GHz bands (EE to O2)[82], whilst the USA has seen many trades, including in the AWS band (AT&T to T-Mobile)[83].

Key learnings: Whilst it is not the only enabling factor, the certainty provided by the award of indefinite spectrum licences will have contributed to the success of these spectrum trades – it is unlikely that such transactions would have occurred in their absence.

We recommend that, where possible, policymakers adopt indefinite licence periods to provide maximum certainty to operators regarding future spectrum availability. Regulators can be concerned that issuing indefinite spectrum licences could potentially make it difficult to change the nature of use of the spectrum in the event that a new use arises. Whilst service and technology neutrality can help, sometimes the underlying conditions of use of the licence (e.g. power transmission rights/characteristics) can prevent other types of use. Even with indefinite duration licences, regulators retain the rights to terminate spectrum usage rights for spectrum management reasons and changes of use that could not be facilitated by the market alone can be facilitated by the regulator – this is not prevented by the existence of indefinite rights of use. For example, in the USA spectrum used for the provision of commercial broadcast television services in the 600-800MHz range have been repurposes for use for mobile services (creating the 600MHz and 700MHz bands) and spectrum used for satellite services (for the provision of space to Earth communications) has again been repurposed for terrestrial mobile use (3.7-4.0GHz range – the so-called ‘C-band’).

Nonetheless, recognising that some regulators may still not be open to indefinite licences, we recommend adopting a minimum licence period of 20 years to ensure that operators can generate sufficient returns from any investments – this has already occurred in, for example, Spain, as highlighted below. Typically, such a duration will allow two cycles of equipment investment.

[77] FCC, ‘Public Notice – Auction of Flexible-Use Service Licenses in the 3.45-3.55 GHz Band for Next-Generation Wireless Services; Notice and Filing Requirements, Minimum Opening Bids, Upfront Payments, and Other Procedures for Auction 110; Bidding to Begin October 5, 2021’, 9 June 2021.

[78] Ofcom, ‘Award of the 700MHz and 3.6-3.8GHz spectrum bands – Information Memorandum’, 13 March 2020.

[79] ECO, ‘ECO Report 03. The licensing of “Mobile Bands” in CEPT’, 9 March 2022.

[80] APT, ‘APT report on information of mobile operators’ frequencies, technologies and license durations in Asia-Pacific countries’, April 2021.

[81] Ofcom, ‘Trade of frequencies in the 1452-1492 MHz band from Qualcomm UK Spectrum Ltd to Vodafone Limited and Hutchison 3G UK Limited’, 22 September 2015.

[82] Telecompaper, ‘Ofcom formally approves spectrum transfer from EE to O2’, 5 November 2020.

[83] Fierce Wireless, ‘FCC approves AT&T’s AWS spectrum transfer to T-Mobile’, 26 April 2012.

Case study: Renewable spectrum licences in Spain

Background: Spain awarded 2×30MHz of 700MHz spectrum in 2021, for a total of EUR1.01 billion.[84] Licences had an initial term of 20 years but will be extended for a further 20 years at zero upfront cost provided that all licence conditions are met, including coverage obligations.[85] The coverage obligations included requirements to cover ports, roads and railway stations, as well as for listed municipalities to be covered by June 2025. The obligations associated with Telefónica's spectrum were more extensive – therefore, the reserve and final auction prices were correspondingly lower.

Key learnings: Spain provided operators with certainty regarding spectrum availability by offering guaranteed renewals for zero upfront fee, providing licence conditions are met, further incentivising operators to meet their coverage obligations. We also note that the reserve price for Telefonica's lot was discounted to account for the cost of additional coverage obligations – this is good practice.

In summary, we recommend that licence durations should be as long as possible (minimum 20+ years duration, ideally indefinite), and this should be coupled with allowing operators to trade spectrum, as this will increase the efficiency of spectrum use.

This recommendation on licence duration is consistent with Article 49[86] of the EECC states:

"Where Member States grant individual rights of use for radio spectrum for which harmonised conditions have been set by technical implementing measures in accordance with Decision No 676/2002/EC in order to enable its use for wireless broadband electronic communications services ('wireless broadband services') for a limited period, they shall ensure regulatory predictability for the holders of the rights over a period of at least 20 years regarding conditions for investment in infrastructure which relies on the use of such radio spectrum, taking account of the requirements referred to in paragraph 1 of this Article. This Article is subject, where relevant, to any modification of the conditions attached to those rights of use in accordance with Article 18.

To that end, Member States shall ensure that such rights are valid for a duration of at least 15 years and include, where necessary to comply with the first subparagraph, an adequate extension thereof, under the conditions laid down in this paragraph."

Effectively this Article requires policymakers to provide "regulatory predictability" over a period of at least 20 years, with spectrum licences to be awarded with a minimum duration of at least 15 years (or longer, as is required to provide regulatory predictability).[87]

[84] Ministry of economic affairs and digital transformation, 'The 700MHz band frequency auction ends', 22 July 2021.

[85] Ministry of economic affairs and digital transformation, 'Order ETD / 534/2021, of May 26, approving the tender documents, particular administrative clauses and technical prescriptions for the granting by auction of concessions for private use in the public domain radio in the 700 MHz band and the corresponding auction', 31 May 2021.

[86] Article 49 of European Union, 'Directive (EU) 2018/1972 of the European Parliament and of the Council of 11 December 2018 establishing the European Electronic Communications Code', 17 December 2018, sets out that "Where Member States grant individual rights of use for radio spectrum for which harmonised conditions have been set by technical implementing measures in accordance with Decision No 676/2002/EC in order to enable its use for wireless broadband electronic communications services ('wireless broadband services') for a limited period, they shall ensure regulatory predictability for the holders of the rights over a period of at least 20 years regarding conditions for investment in infrastructure which relies on the use of such radio spectrum, taking account of the requirements referred to in paragraph 1 of this Article."

[87] European Union, 'Directive (EU) 2018/1972 of the European Parliament and of the Council of 11 December 2018 establishing the European Electronic Communications Code', 17 December 2018.

5.2.4 Design of renewal process

Once the licence conditions have been defined, the next step is to assess the appropriate format to use to achieve the award's priorities within the stated timeline.

Regulators have historically relied on a variety of different award formats to make spectrum available:

- **Administrative licence renewals**: Occasionally, licences have simply been extended for the existing licence holders, often as a result of there being no demand from other parties.
- **Auctions**: Spectrum auctions are the most commonly used mechanism to award spectrum and typically award spectrum to the bidder that is prepared to pay most for the spectrum. Auctions have been used for over 80 awards in Europe over the last 10 years.
- **Partial renewal**: Partial renewal is a hybrid administrative/auction processes, within which existing licensees are guaranteed renewal for part of their spectrum to provide them with a minimum quantity to ensure service contiguity whilst allowing competition for remaining spectrum.
- **Beauty contests**: Historically, spectrum has at times been awarded through beauty contests, where bidders have to signal their plans with respecting to meeting a number of qualitative scoring criteria set by the regulator (in line with its priorities).

Within this section, we focus on administrative renewals, auctions and partial renewal processes, with specific reference to previously allocated spectrum (i.e. renewals). We will not discuss beauty contests in detail. This is because beauty contests are subject to subjective scoring by individuals and lack transparency – they have therefore stopped being used in most countries (Japan being a notable exception, being discussed as a case study below).

We also exclude national wholesale networks from discussion here. In these processes, spectrum is awarded to a national infrastructure provider with the intention of setting up a common network that all mobile operators can use. However, this approach is typically used only for new spectrum and is therefore not relevant here. Furthermore, whilst several countries have announced plans for national wholesale networks in recent years, they have so far struggled to gain significant traction – with the Mexican wholesale operator going bankrupt and plans for a South African network being shelved.

5.2.4.1 Administrative licence renewal

One option for the award process is direct licence renewal via an administrative process. This may be appropriate in cases where demand does not outstrip supply (i.e. the supply of spectrum exceeds demand from existing holders of spectrum and any other parties, such as mobile operators without any holdings in the band). If demand is unclear, an initial industry consultation could be undertaken to understand this, allowing an informed decision to be made with regard to the award type. The primary benefit of this approach is that it provides certainty to existing licensees.

Once a decision has been made to pursue an administrative renewal process, it is necessary to consider the details of the process. The exact nature of administrative renewal processes differs between countries, but there are typically two types:

- The first is a simple renewal/extension of existing spectrum holdings, in which all current licensees retain their existing spectrum under the same licence terms, often with no significant upfront fees (but possibly with annual licence fees).
- The second is more complex, with licences being renewed/extended in exchange for changes to the licence conditions, potentially with benefits to both licensees and policymakers. The nature of

the changes to licence conditions varies in depending on the regulator's objectives but may include obligations to extend coverage or redistribution of spectrum between operators.

To decide the necessary changes to licence conditions, policymakers must firstly consider their objectives for the renewal process. Simple licence extension/renewal is only appropriate in situations where there is no excess demand, there is no possibility of the renewal creating an artificial barrier to market entry, and the regulator's objectives in terms of coverage and competition will continue to be satisfied under the current licence conditions. Otherwise, alterations to licence terms will be necessary.

If improving coverage/availability of services is a priority, the regulator could enter discussions with licensees with regards to how its objectives might be achieved (whilst acknowledging that operators will incur costs). For example, it could work with industry to agree commitments to expand network coverage in exchange for lower spectrum fees – this would likely yield much greater long-term benefits for the economy than higher spectrum fees, a point which has been highlighted by the GSMA which estimates that 5G will benefit the global economy by >USD960 billion annually by 2030.[88] Such an approach has been pursued in both France and Japan, as highlighted in the case studies below.

If competition in the mobile market is a concern, the regulator could work with operators to identify an appropriate rebalancing of spectrum holdings (e.g. ensuring operators that do not have existing holdings in the band can secure spectrum). An industry-driven solution is likely to be a simpler way of achieving such rebalancing of spectrum holdings than conducting an auction. We highlight the examples of France and Denmark below, within which spectrum has been renewed administratively in exchange for industry agreements to redistribute spectrum (plus coverage commitments, in the case of France) – these processes provided certainty to existing licensees whilst continuing to promote competition through spectrum redistribution.

[88] GSMA, 'The Mobile Economy 2022', 28 February 2022.

Case studies – Different administrative renewal processes

Denmark – Licence renewal in exchange for entrant spectrum access

Background: The Danish regulator, NITA, refarmed 900/1800MHz spectrum in 2009, removing technology restrictions, extending licence durations and redistributing spectrum, all at zero upfront cost.[89] 900MHz licences were due to expire in 2011/2012 but were extended until 2019 (1800MHz expiries remained unchanged). In exchange, the existing operators agreed to a redistribution of the spectrum and to make spectrum available for a fourth operator via a separate auction process[90].

Key learnings: Whilst reserving spectrum for a fourth entrant is not necessarily best practice, this example shows how extending 900MHz licences and removing technology restrictions provided operators with certainty, whilst allowing NITA to achieve its objectives without a complex auction.

France – Industry solution exchanging coverage commitments for auction fees

Background: In 2018, the French regulator, ARCEP, engaged industry to sign a "New Deal for Mobile" when 900MHz, 1800MHz and 2.1GHz spectrum was up for renewal. Whilst technically an auction, the process effectively included a renewal at zero upfront cost in exchange for operators' agreeing to invest in coverage and redistribute 900MHz and 2.1GHz spectrum equally between all operators.[91, 92] The operators' committed to a ~EUR3bn investment to improve rural coverage, achieve ubiquitous 4G coverage, and improve transport corridor coverage and indoor services.

Key learnings: With licences expiring at various points in 2021, 2022 and 2024, starting the renewal process in 2018 provided operators with certainty and created a platform for investment, further enabled by ARCEP's decision to waive auction fees in exchange for coverage commitments.

Japan – Beauty contest rewarding commitments in 5G

Background: Japan typically awards spectrum via administrative processes. The 2019 award for 3.6-4.1GHz, 4.5-4.6GHz and 28GHz spectrum was a beauty contest, with criteria including 5G investment, 5G launch date, 5G coverage (using the awarded bands) and MVNO customers. [93,94]

Key learnings: The process traded off revenue generation against 5G coverage commitments. However, concerns remain around transparency – whilst this award type appears to work in Japan, beauty contests place a strong obligation on decision makers to score as objectively as possible.

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[89] GSMA, '900MHz and 1800MHz band refarming case study. Denmark', 24 November 2011.

[90] Telegeography, 'Telestyrelsen awards 900MHz, 1800MHz licences to Hi3G', 14 October 2010.

[91] ARCEP, 'Mobile coverage. New Deal Mobile. Implementation of new mobile coverage targets: Launch of the frequency reallocation procedure, and writing new obligations into operators' licences', 2 August 2018.

[92] ARCEP, '900MHz, 1800MHz and 2.1GHz bands: ARCEP opens a public consultation on the terms and methods for reallocating longstanding mobile telephony frequencies', 5 April 2018.

[93] Communication Infrastructure Bureau, 'Certification of a plan to open a specific base station for the introduction of the 5th generation mobile communication system (5G) (Overview)', April 2019.

[94] Communication Infrastructure Bureau, 'Examination results related to the approval of the establishment plan of a specific base station for the introduction of the 5th generation mobile communication system', April 2019.

5.2.4.2 Auction

In those situations where the demand for spectrum exceeds the supply, then a competitive award process such as an auction is typically appropriate. Adopting such an approach has multiple benefits, including increased transparency in the award process with allocation decisions being made based on objective criteria. Furthermore, auctions do not typically discriminate between existing licensees and potential new entrants, although there are exceptions to this.

Overall, whilst auctions present their own difficulties, they do address many of the concerns associated with administrative renewal processes (e.g. in terms of transparency). However, the auction design should take account of the risks and uncertainties that operators face in a spectrum renewal process.

We make detailed suggestions on ways the auction process can be adapted accordingly in Section 5.2.5. Before doing so, we highlight some of the key considerations to be made herein.

Firstly, we note that in situations where the key policy objective is extending network coverage, the award process can be designed to take account of this – for example, by associating coverage obligations with specific lots or by offering spectrum price discounts in exchange for coverage commitments.

In addition, it is important that regulators and auction advisors focus on the main objectives of the award process – and do not get distracted by the dynamics of the auction process itself. We have observed situations in which policymakers are concerned about a possible lack of competition in an auction process and adjust the spectrum packages, competition rules (e.g. spectrum caps) and/or detailed bidding rules in order to create artificial competition – for example, we note the case of Italy's 3.5GHz auction, details of which are provided later in this section.

However, rarely (if ever) is a competitive auction the objective of the regulator – instead, the principal objectives of the regulator are encouraging competition and investment in the downstream mobile market. Whether or not an auction is competitive should not be relevant provided the objectives of the award process are met – but this can sometimes be forgotten.

5.2.4.3 Partial renewal

Competitive award processes (i.e. auctions) are typically appropriate in situations where demand for spectrum exceeds supply, as highlighted above. However, there are complicating factors where existing spectrum is being re-awarded. Therefore, in such cases the use of a partial renewal format should be considered – partial renewal is hybrid process in which part of the spectrum is awarded via administrative renewal whilst the remaining spectrum is awarded via a competitive award process.

One of the biggest risks faced by operators in spectrum renewal processes concerns business continuity. Without access to certain spectrum, an operator may not be able to continue supporting a given technology (e.g. 2G). Article 50(2)[95] of the EECC requires policymakers "to avoid severe service disruption" when renewing spectrum rights.

The vast majority of the risk faced by operators could be removed by regulators offering existing licensees guaranteed renewal of part of their spectrum holdings in a band (e.g. 2×5MHz of 900MHz spectrum), ensuring a sufficient amount of spectrum is available to ensure they can continue to offer

[95] Article 50(2) of European Union, 'Directive (EU) 2018/1972 of the European Parliament and of the Council of 11 December 2018 establishing the European Electronic Communications Code', 17 December 2018, sets out that "In taking a decision pursuant to paragraph 1 of this Article, competent authorities shall consider, inter alia: ….. (f) the need to avoid severe service disruption.'

services to customers. The remaining spectrum could then be made available in a competitive award process (e.g. using a tried-and-tested auction format).

Such an approach would only be appropriate in situations where the partial renewal is economically efficient and does not risk distorting competition in the mobile market. An example of this is provided in the following case study of Belgium – by providing a certain amount of spectrum to all existing operators prior to the auction, operators were guaranteed to be able to continue operating existing 2G/3G/4G networks.

Case study: Belgium reserves spectrum in existing spectrum bands for incumbent operators

Background: BIPT, the Belgian regulator, is planning a multi-band spectrum auction for June 2022, within which it has reserved 2×5MHz of 900MHz, 2×15MHz of 1800MHz, and 2×10MHz of 2.1GHz spectrum for existing licence holders.[96]

Key learnings: This is an example of a partial renewal because each incumbent operator will be guaranteed access to a minimum quantity of spectrum at a fixed price. It therefore provides operators with a degree of certainty regarding future spectrum availability, removing much of the risk whilst still allowing the most efficient spectrum allocation to be determined via auction. This is good practice; however, there are other aspects of this auction process which do not necessarily correspond with best practice (e.g. the process has been delayed several times, potentially impacting 5G deployment).

Partial renewal is primarily relevant in the short-term where we have mobile technologies (such as 2G and 3G) that can only be deployed in specific frequency bands. Once operators have multiple bands in lo, mid and high-band spectrum and, over time, as all mobile technologies can be deployed across multiple bands, the level of risk faced by an operator in respect of an individual band is significantly lower and a partial renewal may not be so relevant. The exception to this may be the case where an operator is facing the renewal of a large number of frequency bands at the same time that represent a large portfolio of its spectrum holdings – in such a case the operator may be facing very high levels of risk and uncertainty and partial renewal could be a solution to this.

5.2.5 Auction best practices

We outlined the situations in which competitive spectrum award processes (i.e. auctions) would be appropriate within Section 5.2.4 above – an auction is typically appropriate if demand for spectrum exceeds supply. In this section, we outline a series of best practices that should be adopted by policymakers if an auction is deemed necessary for previously assigned spectrum. These are:

- **Avoiding risky or complex auction formats/rules:** To reduce the uncertainty faced by operators, the use of any unduly risky or complex auction formats should be avoided. Instead, we recommend use of simple 'tried and tested' simple formats (e.g. SMRA, Clock).
- **Ensuring the auction does not unduly impact on natural evolution of the market:** Policymakers should avoid auction rules which aim to 'force' changes to the market structure (e.g. spectrum reservations), with the aim of allowing existing players to continue operating.
- **Prioritising non-monetary objectives, such as coverage:** If expanding connectivity is an aim, regulators should consider lowering spectrum fees in return for coverage commitments.

[96] BIPT, 'Procedure for the granting of rights of use for the 700 MHz, 900 MHz, 1400 MHz, 1800 MHz, 2100 MHz and 3600 MHz frequency bands – Information Memorandum – Version 1', 14 January 2022.

In the rest of this section, we provide detailed best practice recommendations on each of the topics above, as well as providing examples of good and bad practice internationally.

Avoiding risky or complex auction formats/rules

To further reduce the risk/uncertainty faced by operators in relation to existing spectrum, we recommend that regulators avoid use of any unduly risky or complex auction formats. We recommend use of simple 'tried and tested' formats and avoid use of formats which can yield highly uncertain outcomes.

Examples of the main auction formats used include:

- First price, sealed bid auctions: Each bidder submits a sealed, one-off bid for each lot/category. The winner is the bidder who submits the highest bid, and it is required to pay the price it bid.
- Simultaneous multi-round ascending auctions (SMRAs): In each round, the auctioneer defines a minimum bid for each lot/category, which is higher than the previous highest bid (or, in the first round, the reserve price). Bidders are then invited to submit bids for each lot/category, with the provisional winner for each lot being the bidder who submits the highest bid. This continues until there are no new bids on any lots in a round, with the spectrum being sold to whoever submitted the highest bid. All successful bidders must pay the price they bid in the final round.
- Clock auctions: The auctioneer sets the price for each lot/category in each round, with the price increasing from one round to the next – this is known as the 'clock price'. In each round, bidders are required to indicate the quantity of spectrum they wish to acquire in each category at the clock price, with the auction continuing until demand is less than or equal to supply. All successful bidders must pay the final clock price for the spectrum.
- Combinatorial clock auctions (CCAs): A more complex auction format, consisting of two stages. The first stage is a clock auction. The second is a sealed bid, within which bidders are invited to submit their best and final offers for all combinations of the available spectrum that they would be interested in acquiring. However, restrictions are placed on the bids one can submit in this second stage – all bids must be consistent with the preferences expressed in the first auction stage. The auctioneer then determines the combination of bids that would maximise the price paid, subject to certain constraints – each lot can only be sold once and only one bid from each bidder can be accepted. The price paid is calculated based on all bids and it is typically below the submitted bid price.

The appropriate choice of auction format will evidently be situation-dependent, with policymakers required to consider the following three components in order to identify a suitable format:

- The theoretical merits of candidate auction formats
- The specific circumstances of the auction (market conditions, policy goals, available spectrum etc.)
- The requirements of bidders due to the practical constraints they face.

However, there are some general principles to which policymakers should adhere. Specifically, the auction format should only be as complex as is required to meet the auction's objectives – complexity should only be added where there is a demonstrable benefit. In addition, the auction format should avoid the final results coming as a surprise at the end of the auction – the final outcome should emerge as the auction evolves, allowing bidders to take corrective action where necessary. Finally, the format should be 'tried and tested' – this is not an environment for experimentation, as this creates uncertainty.

If these principles are adhered to, auctions can have many benefits, allowing an efficient allocation of spectrum to be achieved within a robust and transparent process. However, the risks of getting it wrong are severe. Therefore, simplicity is key – it reduces uncertainty and risk for all concerned.

We outline examples of good and bad practice with regards to auction design in the case studies below. Finland is positive example of what might be achieved by adopting a pragmatic, tried and tested approach to spectrum auctions. Meanwhile, the case of Ireland highlights the risks of unnecessary complexity – the separation of spectrum licences into multiple time-slices has resulted in an unnecessarily complex auction with significant risks.

Finally, we note the example of Tele 2 (previously discussed in Section 3.3), which was forced to exit the Norwegian mobile market as a result of failing to re-acquire its existing 900MHz spectrum holdings at auction. One of the main contributing factors was the selected auction format: first price, sealed bid. This auction format raises significant problems from a bidding strategy perspective because participants are only permitted to enter a single bid and, if successful, are obliged to pay their full bid price.

Operators aim is always to pay as little as possible for spectrum (i.e. as far below its theoretical value as possible), to generate a surplus and enable them to direct investment at network deployment. However, in a first price, sealed bid auction, the lower they bid, the less likely they are to win spectrum and vice versa. Furthermore, it is not able to increase one's bid if unsuccessful. Therefore, bidding strategy effecting becomes a 'guessing game' – operators are estimating the minimum price they need to outbid their competitors without any indication of what this might be.

Tele2 lost this 'guessing game', submitting the lowest bid for spectrum and not acquiring any 900MHz spectrum as a result. However, that does not necessarily mean its value for the spectrum was lowest. That is the main flaw of first price, sealed bid auctions – they do not incentivise participants to bid to value and are therefore prone to producing inefficient outcomes. Other auction formats have their own flaws and therefore the appropriate format is dependent on the auction's objectives. However, this is a powerful example of what can happen if regulators get it wrong.

Case studies – Different approaches to auction complexity

Finland – Pragmatic approach to spectrum auctions

Background: Finland has conducted multiple spectrum auctions, typically achieving successful outcomes. It tends to avoid unnecessary complexity, ensuring spectrum is awarded and deployed swiftly. Finland relies on tried-and-test formats (typically the SMRA[97] format) and uses a pragmatic approach to spectrum caps and packaging. For example, in its 700MHz auction in 2016, six lots of 2×5MHz were auctioned with a spectrum cap of 2×10MHz.[98,99] With three incumbent operators, each of them was guaranteed equal access to spectrum, unless an entrant were to participate.

Key learnings: In adopting a simplified auction process, Finland retains many of the benefits of competitive awards whilst avoiding common pitfalls. It provides transparent outcomes with equal access to spectrum, whilst offering new entrants the opportunity to bid for spectrum on equal terms with incumbents. At the same time, it prevents auctions from becoming unduly lengthy if only the incumbents participate.

Ireland – Unnecessary complexity through time slicing

Background: The upcoming Irish auction is an example where complex auction and licence conditions may have a negative impact on network investments. Later this year, the Irish regulator, ComReg, intends to award 700MHz, 2.1GHz, 2.3GHz and 2.6GHz spectrum via auction. Spectrum licences in all bands but the 700MHz are awarded for two time slices, the first covering the period to March 2027 and the second covering the period from March 2027 to February 2042.[100] The reason for spectrum being awarded in two time slices is to align with the expiry dates of existing 2.1GHz licences.

Key learnings: Whilst timing slicing is an innovative approach, for new spectrum bands (2.3/2.6GHz) it presents a number of challenges – specifically an operator may only invest in these bands if it gains access to the spectrum until 2042. One potential impact of the time slices could be that operators only acquire spectrum in the later period, thereby delaying network investments, to the detriment of all parties concerned.

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[97] Simultaneous Multi Round Ascending (SMRA)

[98] Fierce Wireless, 'Finland to hold 700 MHz spectrum auction in November', 10 October 2016.

[99] Ministry of Transport and Communications, 'The Government adopted a decision on the details of the 700 MHz spectrum auction', 6 October 2016.

[100] ComReg, 'Multi Band Spectrum Award – Information Memorandum and Draft Regulations. The 700MHz Duplex, 2.1GHz, 2.3GHz and 2.6GHz Bands ', 16 April 2021.

Ensuring that the auction does not unduly impact on natural evolution of the market

We recommend that the auction design and rules do not prevent natural evolution of the underlying market (e.g. forcing a new entrant through a spectrum reservation or forcing consolidation through limiting supply of spectrum).

Specifically, we refer here to (i) avoiding artificial market entry where there is no desire and/or proven need for it given the market context, and (ii) ensuring that the auction process imposes reasonable restrictions on operators' acquisition options, both to avoid spectrum hoarding and to ensure a minimum quantity of spectrum is available for all operators, whilst acknowledging the importance of ensuring that all spectrum is awarded and does not remain unassigned for long periods of time.

On the first point, we note the positive example of Sweden, which renewed 900MHz spectrum administratively in exchange for redistribution of the spectrum between all incumbent operators. However, there are also negative examples, including that of the Netherlands which has used spectrum reservations on multiple occasions, resulting in high spectrum prices and windfall profits.

On the second point, we note the examples of Slovakia and Belgium below. Slovakia adopted good practice in its spectrum caps for its recent 3.5GHz auction, ensuring all operators could acquire a meaningful quantity of spectrum whilst allowing for caps to be relaxed if spectrum remained unassigned. Meanwhile, Belgium adopted tight inflexible caps that resulted in spectrum remaining unassigned – this is clearly a negative outcome for consumers.

Case studies – Auction processes supporting natural market evolution

Sweden – 900MHz renewal based on industry proposals

Background: PTS, the Swedish regulator, conducted a refarming processes for spectrum in the 900MHz band in 2009. This was an administrative process based on industry proposals for the sharing of spectrum between operators and included the redistribution of spectrum to ensure all operators had access to a minimum quantity. This process included renewing the licences of incumbent licensees (with new expiry dates of 31 December 2025), as well as expanding the 900MHz band from 2×30MHz to 2×35MHz and relaxing technology restrictions.[101] The process also included the transfer of 2×5MHz of spectrum (2×2.5MHz each from Tele2 and Telenor) to Hi3G, which did not have prior access to 900MHz spectrum, and the redistribution of spectrum to ensure that each operator's holdings were contiguous. The outcome was that all five incumbent operators had access to at least 2×5MHz of 900MHz spectrum.

Key learnings: In this case, the adoption of an administrative process provided certainty to operators regarding future spectrum availability and pricing, whilst achieving the regulator's objective of redistributing spectrum to ensure that all operators had access to a sufficient quantity to compete effectively. It also avoided the need for a potentially complex auction procedure.

Slovakia – Flexible spectrum caps enabling different demand scenarios

Background: Slovakia's 3.5GHz auction included 400MHz of spectrum, split into 40 lots of 10MHz each. One of these lots (3400-3410MHz) was deemed to be of limited use due to interference from radar and was therefore offered at zero upfront cost to the operator who acquired the 3410-3420MHz lot. The auction rules also defined a cap of 100MHz, which was to be relaxed to 140MHz if spectrum were to remain unassigned after the first stage of the auction. A minimum bid of 80MHz was also defined.[102]

Key learnings: There are four operators in Slovakia, the rules thus guaranteed 90MHz to each operator in the first stage of the auction, provided no new entrants bid. However, they addressed the possibility of unassigned spectrum by allowing the cap to be relaxed if spectrum was unassigned after the first stage. This is an example of how auctions may guarantee all operators access to a minimum quantity of spectrum whilst enabling the market to determine the efficient allocation.

[101] GSMA, '900MHz band refarming case study – Sweden', 29 November 2011.

[102] Telegeography, 'Slovakia lays out terms for 3.5GHz auction in May', 7 March 2022.

Case studies – Auction processes disrupting natural market evolution

Netherlands – Entrant reservations lead to high auction prices and windfall profits

Background: Spectrum auctions were held in the Netherlands in 2010 and 2012, including spectrum reservations for new entrants in the 2.6GHz and 800MHz bands, respectively. Tight spectrum caps in the 2010 auction effectively reserved 2.6GHz spectrum for new entrants.[103] Ultimately, 2×40MHz was acquired by two new entrants: 2×20MHz each for Tele2 and Ziggo.[104] In addition, all of the 2.6GHz TDD spectrum in the auction remained unsold. Overall, this was an inefficient outcome. In the 2012 auction, 2×10MHz of 800MHz spectrum was reserved for new entrants.[105] This created spectrum scarcity for the incumbents, resulting in competitive bidding for the non-reserved 800MHz spectrum. This resulted in a 300% price differential between reserved and non-reserved spectrum – the reserved spectrum was acquired below its market value by Tele2.[106]

Key learnings: Neither Tele2 nor Ziggo had made use of the reserved 2.6GHz spectrum at the time of their subsequent mergers with T-Mobile/Vodafone, many years after the auction.[107,108] Moreover, in 2017, Tele2 merged with T-Mobile without having deployed significant network assets. The net effect of these reservations were thus windfall profits for Ziggo's / Tele2's shareholders, with the spectrum remaining underutilised for a long period of time.

Belgium – Tight spectrum caps lead to unsold spectrum

Background: Belgium's 2.6GHz auction in 2011 attempted to encourage market entry by effectively reserving spectrum for a fourth participant through the application of a spectrum cap – the cap was set at 2×20MHz, with 2×70MHz of spectrum being available, resulting in a reservation of 2×10MHz.[109] However, interest from potential new entrants was not forthcoming and, as there was no mechanism by which the cap could be relaxed, 2×15MHz of spectrum went unassigned.[110]

Key learnings: The unsold spectrum illustrates that this was clearly an inefficient auction denying Belgian consumers of the potential benefits of this spectrum being used by incumbent operators.

Prioritising non-monetary objectives, such as coverage

If expanding network coverage is the key policy objective, regulators should consider accepting lower spectrum fees in return for operator commitments to expanding mobile coverage/5G deployment.

[103]State Secretary for Economic Affairs, 'Regulation of the State Secretary for Economic Affairs of October 18, 2009, no. WJZ/9155615, establishing the application and auction procedure for licenses for frequency space in the 2.6 GHz band for mobile communication applications (Regulations for application and auction procedure licenses 2.6GHz)', 18 October 2009

[104]Telegeography, 'State awards mobile frequencies: Ziggo, Tele2 emerge as big winners', 23 April 2010.

[105]The Dutch Ministry of Economic Affairs, Agriculture and Innovation, 'Regulation of the Dutch Ministry of Economic Affairs, Agriculture and Innovation dated January 6th, 2012, no. WJZ/10146523, to establish the application and auction procedure for licences for the frequency spectrum in the 800, 900 and 1800 MHz bands for mobile communication applications (Regulation regarding the application and auction procedure for 800, 900 and 1800 MHz licences', 6 January 2012.

[106]Telegeography, '4G auction raises USD5bn for Dutch coffers', 17 December 2012.

There are myriad benefits of expanding connectivity, both social and economic, with the potential to have a major impact – for example, the GSMA estimates that 5G will benefit the global economy by >USD960 billion annually by 2030, as highlighted previously.[111] These benefits arise across a wide range of industries, with 5G having the potential to increase both productivity and sustainability.

Given the magnitude of the knock-on benefits of non-monetary spectrum award objectives, they should be prioritised. However, we highlighted previously how spectrum fees and coverage obligations are both key components of the TCSO. Therefore, if policymakers' objectives include the expansion of network coverage (or other non-monetary objectives), it is important to acknowledge the costs that operators will incur in achieving these objectives. Specifically, it may be appropriate for spectrum prices to be reduced in exchange for operators' agreement to address policymakers' non-monetary objectives.

Ultimately, the social inclusion and economic growth benefits from greater connectivity and faster access to 5G services will yield considerably greater economic value for the country than any short-term gains from higher auction revenues. Furthermore, the income for governments will ultimately be greater as a result of the additional taxes that will be raised as a result of the greater economic growth (e.g. additional sales tax/VAT, additional corporation tax and additional taxes associated with employment (income tax, employee and employer social security contributions etc).

We highlight the examples of Sweden and Austria below, both of which have offered discounts on spectrum prices in exchange for operators' commitments to increasing coverage.

[107]Telegeography, 'Ziggo-Vodafone merger approved by EC; Vodafone to divest fixed assets', 4 August 2016.

[108]Telegeography, 'Double Dutch: T-Mobile-Tele2 merger concludes', 3 January 2019.

[109]BIPT, 'Auction of the user rights for radio access systems in the 2500-2690MHz band – Auction rules', 1 April 2011.

[110]BIPT, 'BIPT makes the results of the 4G auction public', 28 November 2011.

[111]GSMA, 'The Mobile Economy 2022', 28 February 2022.

Case studies – Auction processes trading off auction fees with coverage commitments

Sweden – Operators bidding on coverage commitments

Background: In the Swedish 700MHz auction of December 2018, 2×20MHz of spectrum was awarded at a price of SEK2.8 billion, including a coverage commitment of SEK300 million that would not be paid as auction fees, but as investment in underserved areas.[112] The commitment was limited to a single 2×10MHz lot, to which coverage and deployment requirements were attached, with bidding capped at SEK300 million.[113] Telia acquired the lot at a price of SEK1.38 billion – as this was in excess of the SEK300m cap, the remaining balance of SEK1.08 billion was paid as auction fees.

Key learnings: Operators were offered a discount in exchange for coverage commitments, allowing the regulator to achieve its coverage aims in exchange for reduced fees.

Austria – Discounting auction fees in exchange for white area coverage

Background: In Austria's 2020 multi-band auction, operators were offered the opportunity, during an additional auction stage, to bid for discounts on their auction fees in exchange for extended coverage obligations (beyond those committed to during the main auction).[114,115]

The regulator outlined which locations it wanted to cover additionally (as operators were offered choice regarding which underserved locations would be covered by their basic coverage obligations). Operators could then indicate which additional locations they would cover at which discount. The coverage obligations and discounts were then assigned to operators in a way that maximised the total locations covered within the regulator's budget. Ultimately, operators committed to cover more than 800 additional locations in exchange for total discounts of ~EUR87 million.[116]

Key learnings: By offering an additional discount on the auction fees, the regulator was able to extend the coverage obligations beyond those already included in the original licences.

[112]PTS, 'Assignment in the 700MHz band', 11 December 2018.

[113]PTS, 'General invitation to apply for permission to use radio transmitters in the 700MHz band', 4 July 2018.

[114]RTR, 'Tender Document in the procedure for awarding spectrum in the 700, 1500 and 2100MHz ranges', 11 December 2019.

[115]RTR, 'Auction rules for the awarding of spectrum in the 700, 1500 and 2100MHz bands', 11 December 2019.

[116]DotEcon, 'Second Austrian 5G auction ends with prospect of substantial improvements in coverage', September 2020.

5.3 The benefits of applying best practice approaches to spectrum renewals

In this section, we have outlined best practice principles for policymakers to follow when renewing spectrum. Renewing spectrum with extended licence periods, well ahead of licence expiry, using either administrative licence renewals where demand does not exceed supply or simple auctions which guarantee partial renewal where demand does exceed supply, would have several benefits:

- Avoiding direct "investment hesitancy" on equipment using the spectrum in the years running up to the expiry of the licences, as well as not putting historic investments at risk (thereby creating unnecessary duplicate investments).
- Reducing the level of risk/uncertainty perceived by mobile operators with expiring spectrum licences, thereby releasing funding for strategic investments such as increasing network coverage.
- Helping to stimulate a secondary market in spectrum, thereby increasing spectral efficiency – for example, if a mobile operator has more certainty in holding Asset A, it may be more inclined to trade a less important Asset B to another party who needs it more/can generate greater value from it.

6. Conclusions

In order to promote investment and thereby increase the chances of achieving the Digital Decade and European Green Deal targets, we make recommendations to policymakers regarding both spectrum pricing and the award process for spectrum renewals – both are vital for successful renewal to be achieved (with the metric of success depending on the regulators' policy objectives).

With regards to spectrum pricing, we recommend that decisions are made in consideration of all aspects of the TCSO, including auction payments, annual licence fees and indirect licence costs, as operators' investment decisions will be dependent on the sum of these components. Ultimately, the spectrum price, and its breakdown between these components, should be set to maximise network investment rather than auction payments if Digital Decade and European Green Deal targets are to be achieved, with the overarching objective of the auction process being to ensure an efficient allocation of spectrum.

With regards to the award process for spectrum renewals, we recommend that policymakers look to lower the risks and levels of uncertainty faced by mobile operators in relation to spectrum licences which are coming up to expiry by adopting best practice in the following areas:

- Timing of renewal process – Conducting spectrum renewal well in advance of licence expiry.
- Objectives of process – Ensuring the priorities/objectives for renewal are understood prior to award.
- Conditions of spectrum use – Awarding licences of at least 20-years, and ideally indefinite licences, coupled with supporting spectrum trading.
- Design of renewal process – Selecting an appropriate award process:
  - Whilst auctions are increasingly the default approach for assigning mobile spectrum, and are a very useful tool, it is worth considering if an administrative renewal of the spectrum can be made in cases where the spectrum demand does not exceed supply. This may involve either the equal distribution of spectrum in the band to all operators or direct renewal of operators' existing holdings.
    - An industry-led solution/distribution of spectrum can be a good means of ensuring spectrum is efficiently assigned and funds that would be spent on a competitive auction can instead be used for expanding network coverage to lessen the digital divide.
  - Using auctions where demand for spectrum exceeds supply, ensuring that policymakers focus on the objectives of the award process and do not get distracted by auction dynamics – the objective should be to encourage competition and investment in the mobile market itself.
  - Considering use of partial renewal for critical parts of operators' spectrum holdings (where this is appropriate and would not adversely affect competition in the market). This is likely to be appropriate in cases where demand for spectrum exceeds supply but there is a business/service continuity risk to existing licensees if they lose key spectrum) – as required by Article 50(2)[117] of the EECC. This approach is particularly important in the short-term where specific technologies (2G/3G) can only be deployed in particular frequency bands.

[117] Article 50(2) of European Union, 'Directive (EU) 2018/1972 of the European Parliament and of the Council of 11 December 2018 establishing the European Electronic Communications Code', 17 December 2018, sets out that "In taking a decision pursuant to paragraph 1 of this Article, competent authorities shall consider, inter alia: ….. (f) the need to avoid severe service disruption.'

- Auction best practices – Where an auction is required, adopting the following best practices:
  - Making use of simple, predictable, well-proven auction designs (e.g. SMRA, Clock) and avoiding complex or risky formats with unpredictable outcomes (e.g. CCA, first price, sealed bid).
  - Ensuring that the auction does not prevent natural evolution of the underlying market (e.g. forcing a new entrant through a spectrum reservation or forcing consolidation through limiting supply of spectrum.
  - Prioritising non-monetary objectives, such as coverage. For example, by accepting lower spectrum fees in return for operator commitments to expanding mobile coverage. Article 42(2)[118] of the EECC sets out that regulators should take account the costs of meeting licence obligations when setting auction reserve prices.

In this report we have separately discussed best practice approaches to award processes and spectrum pricing. However there is often a linkage between these two issues – a successful outcome can only be achieved if best practice is followed with respect to both. This is illustrated, for example, by the fact that a particular auction design can work well in one situation whilst leading to unassigned spectrum in another, as a result of the spectrum pricing decisions made:

Case study: Clock auctions result in very different outcomes in Romania and Sweden

Background: Romania applied a Clock format in both its 2012 and 2021 multi-band spectrum auctions. However, the success of these auctions was limited, with large quantities of spectrum remaining unassigned in both cases, including in the 800MHz and 2.6GHz bands. As highlighted previously, the main reason for spectrum remaining unassigned was the high reserve prices associated with spectrum, particularly the annual licence fee component. The failure to assign all spectrum was clearly an inefficient outcome, detrimental to both operators and consumers.

In contrast, several countries have successfully assigned spectrum using the Clock format. For example, the Swedish regulator, PTS, used a Clock format for its auction of 2.3GHz and 3.5GHz spectrum in 2021.[119] This auction resulted in all spectrum being successfully assigned, with each of the four bidders acquiring at least 80MHz of 5G-suitable spectrum.[120]

Key learnings: These contrasting examples illustrate how, when allocating spectrum, all elements of the award procedure and licence conditions must be considered to achieve a successful outcome.

Fundamentally, policymakers should always keep in mind that spectrum assignment and pricing decisions can have a significant impact on mobile operators and the functioning of the mobile market. Poor decisions by policy makers could result in operators either not acquiring the portfolio of spectrum that they require or having to pay a high price to obtain the spectrum that the need. This fundamentally damages their ability to invest in the widespread deployment of new technologies including 5G.

[118]–Article 42(2) of European Union, 'Directive (EU) 2018/1972 of the European Parliament and of the Council of 11 December 2018 establishing the European Electronic Communications Code', 17 December 2018, sets out that "With respect to rights of use for radio spectrum, Member States shall seek to ensure that applicable fees are set at a level which ensures efficient assignment and use of radio spectrum, including by: (a) setting reserve prices as minimum fees for rights of use for radio spectrum by having regard to the value of those rights in their possible alternative uses; (b) taking into account costs entailed by conditions attached to those rights; and (c) applying, to the extent possible, payment arrangements linked to the actual availability for use of the radio spectrum."

[119]PTS, 'Open invitation to apply for licences to use radio transmitters in the 3.5GHz and 2.3GHz bands', 17 April 2020.

[120]PTS, 'Decision on permission to use radio transmitters in the 3.5 GHz and 2.3 GHz bands', 20 January 2021.

In contrast, policymakers that de-risk the spectrum renewal process facing mobile operators will enable those operators to release funds that can be used for strategic purposes, such as expanding the coverage of their networks. In turn, this will reduce the 'investment gap' which the government then needs to fill. In other words, it will increase the likelihood and lower the cost to the public of meeting the connectivity ambitions in the Digital Decade vision for 2030. This, in turn, increases the likelihood of Europe meeting the sustainability/emissions targets of the European Green Deal.

Annex A Upcoming spectrum renewals in Europe

In this Annex, we provide further details of upcoming spectrum renewals in Europe. Figure A-1 below lists the spectrum bands in individual countries within the European Economic Area (EEA), plus Switzerland and the United Kingdom, where licences are due to expire in the next 10 years (by December 2032). The information contained in this table was summarised within Figure 3-7.

Figure A-1: Spectrum bands due to expire in Europe in the next ten years [Source: European Communications Office[121,122] and European 5G Observatory[123]]

Country	Band	Operator	Expiry date	Remarks
Austria	800MHz FDD	A1	December 2029	
		T-Mobile	December 2029	
	2.6GHz FDD	A1	December 2026	
		T-Mobile	December 2026	
		Drei	December 2026	
	2.6GHz TDD	A1	December 2026	
		Drei	December 2026	
Belgium	2.6GHz FDD	Proximus	June 2027	
		Telenet	June 2027	
		Orange	June 2027	
	2.6GHz TDD	Dense Air	June 2027	
	3.5GHz TDD	Gridmax	May 2025	
		Citymesh	May 2025	
		Proximus	June 2022	
		Telenet	June 2022	
		Orange	June 2022	
Bulgaria	900MHz FDD	Bulgarian Company	June 2024	
		A1	June 2024	
		Telenor	January 2031	

[121]European Communications Office, 'ECO Report 03: The Licensing of "Mobile Bands" in CEPT', 9 March 2022.

[122]European Communications Office, 'ECO Report 03: The Licensing of "Mobile Bands" in CEPT', 6 April 2021.

[123]European 5G Observatory, 'Belgium grants provisional 5G licences in the 3.5GHz band', 15 May 2020.

	1800MHz FDD	Bulgarian Company	June 2024
		A1	June 2024
		Telenor	January 2031
	2.1GHz FDD	Bulgarian Company	April 2035
		A1	April 2035
		Telenor	April 2035
Croatia	800MHz FDD	A1	October 2024
		Hrvatski Telekom	October 2024
	900MHz FDD	A1	October 2024
		Hrvatski Telekom	October 2024
		Telemach	December 2024
	1800MHz FDD	A1	October 2024
		Hrvatski Telekom	October 2024
		Telemach	December 2024
	1900MHz TDD	A1	October 2024
		Hrvatski Telekom	October 2024
		Telemach	December 2024
	2.1GHz FDD	A1	October 2024
		Hrvatski Telekom	October 2024
		Telemach	December 2024
	2.6GHz FDD	A1	December 2024
		Hrvatski Telekom	December 2024
		Telemach	December 2024
	3.5GHz TDD	O Telekomunikacije	November 2023
Cyprus	800MHz FDD	Epic	September 2028
		Cyta	September 2028
		Cablenet	June 2029
	900MHz FDD	Epic	December 2023
		Cyta	February 2024
		Primetel	February 2029

	1800MHz FDD	Epic	December 2023
		Cyta	February 2024
		Primetel	February 2029
	2.1GHz FDD	Epic	December 2023
		Cyta	February 2024
		Primetel	February 2029
	2.6GHz FDD	Epic	September 2028
		Cyta	September 2028
		Cablenet	June 2029
	2.6GHz TDD	Epic	September 2028
		Cyta	September 2028
		Cablenet	June 2029
Czech Republic	800MHz FDD	O2	June 2029
		T-Mobile	June 2029
		Vodafone	June 2029
	900MHz FDD	O2	October 2024
		T-Mobile	October 2024
	1800MHz FDD	O2	October 2024
		O2	June 2029
		T-Mobile	October 2024
		T-Mobile	June 2029
		Vodafone	June 2029
	1900MHz TDD	T-Mobile	October 2024
	2.1GHz FDD	T-Mobile	October 2024
		Vodafone	February 2025
	2.6GHz FDD	O2	June 2029
		T-Mobile	June 2029
		Vodafone	June 2029
	2.6GHz TDD	O2	June 2029
		T-Mobile	June 2029

	3.5GHz TDD	O2	June 2032
		Vodafone	June 2032
		POD	June 2032
		Nordic Telecom 5G	June 2032
Denmark	2.6GHz FDD	TDC	May 2030
		Hi3G	May 2030
		Telia	May 2030
		Telenor	May 2030
	2.6GHz TDD	Hi3G	May 2030
		Telia	May 2030
		Telenor	May 2030
	26GHz FDD	Telia	December 2025
		Telenor	December 2026
Estonia	800MHz FDD	Tele2	January 2030
		Elisa	February 2030
		Telia	February 2030
	900MHz FDD	Tele2	January 2030
		Elisa	February 2030
		Telia	February 2030
	1800MHz FDD	Tele2	January 2030
		Elisa	February 2030
		Telia	February 2030
	1900MHz TDD	Tele2	January 2030
		Elisa	February 2030
		Telia	February 2030
	2.1GHz FDD	Tele2	January 2030
		Elisa	February 2030
		Telia	February 2030
	2.3GHz TDD	Tele2	May 2030
	2.6GHz FDD	Elisa	February 2030

		Elisa	June 2030
		Telia	February 2030
		Telia	April 2030
	2.6GHz TDD	Elisa	June 2030
Finland	2.6GHz FDD	DNA	February 2029
		Telia	February 2029
		Elisa	February 2029
	2.6GHz TDD	Elisa	February 2029
France	800MHz FDD	Bouygues Telecom	January 2032
		SFR	January 2032
		Orange	January 2032
	900MHz FDD	Bouygues Telecom	December 2024
		SFR	March 2031
		Orange	December 2024
		Orange	February 2025
		Orange	March 2031
		Free	January 2030
		Free	March 2031
	1800MHz FDD	Bouygues Telecom	December 2024
		SFR	March 2031
		Orange	March 2031
		Free	October 2031
	1900MHz TDD	Bouygues Telecom	December 2022
	2.1GHz FDD	Bouygues Telecom	December 2032
		SFR	August 2031
		Orange	June 2030
		Orange	August 2031
		Free	January 2030
		Free	August 2031
	2.6GHz FDD	Bouygues Telecom	October 2031

		SFR	October 2031
		Orange	October 2031
		Free	October 2031
	3.5GHz TDD	28 regional licences	On or before July 2026
Germany	800MHz FDD	Deutsche Telekom	December 2025
		Telefónica	December 2025
		Vodafone	December 2025
	1800MHz FDD	Deutsche Telekom	December 2025
		Telefónica	December 2025
	1900MHz TDD	Telefónica	December 2025
	2.1GHz FDD	Telefónica	December 2025
		Vodafone	December 2025
		Erste MVV Mobilfunk VermÖgensverwaltungs	December 2025
	2.6GHz FDD	Deutsche Telekom	December 2025
		Telefónica	December 2025
		Vodafone	December 2025
		Erste MVV Mobilfunk VermÖgensverwaltungs	December 2025
	2.6GHz TDD	Deutsche Telekom	December 2025
		Telefónica	December 2025
		Vodafone	December 2025
		Erste MVV Mobilfunk VermÖgensverwaltungs	December 2025
Greece	800MHz FDD	Wind	February 2030
		Vodafone	February 2030
		Cosmote	February 2030
	900MHz FDD	Wind	September 2027
		Vodafone	September 2027
		Cosmote	September 2027
	1800MHz FDD	Vodafone	November 2027

		Cosmote	November 2027
	2.6GHz FDD	Wind	February 2030
		Vodafone	February 2030
		Cosmote	February 2030
	2.6GHz TDD	OTE	April 2029
		Vodafone	March 2030
		Cosmote	March 2030
Hungary	800MHz FDD	Magyar Telekom	June 2029
		Vodafone	June 2029
		Telenor	June 2029
	900MHz FDD	Magyar Telekom	June 2029
		Vodafone	June 2029
		Telenor	June 2029
	2.6GHz FDD	Magyar Telekom	June 2029
		Vodafone	June 2029
		Telenor	June 2029
	2.6GHz TDD	Vodafone	June 2029
Iceland	700MHz FDD	Síminn	July 2032
	800MHz FDD	Nova	April 2023
		Nova	July 2032
		Sýn	April 2023
		Sýn	July 2032
	1800MHz FDD	Síminn	April 2023
		Nova	April 2023
		Sýn	April 2023
	2.6GHz FDD	Síminn	July 2032
		Nova	July 2032
		Sýn	July 2032
Ireland	800MHz FDD	Eir	July 2030
		Three	July 2030

		Vodafone	July 2030
	900MHz FDD	Eir	July 2030
		Three	July 2030
		Vodafone	July 2030
	1800MHz FDD	Eir	July 2030
		Three	July 2030
		Vodafone	July 2030
	1900MHz TDD	Three	October 2022
	2.1GHz FDD	Eir	March 2027
		Three	July 2022
		Three	October 2022
		Vodafone	October 2022
	3.5GHz TDD	Vodafone	July 2032
		Dense Air	July 2032
		6 regional licences	July 2032
	26GHz TDD	Eir	August 2028
		Three	August 2028
		Vodafone	August 2028
Italy	800MHz FDD	Wind Tre	December 2029
		Telecom Italia	December 2029
		Vodafone	December 2029
	900MHz FDD	Wind Tre	December 2029
		Telecom Italia	December 2029
		Vodafone	December 2029
	1500MHz SDL	Telecom Italia	December 2029
		Vodafone	December 2029
	1800MHz FDD	Wind Tre	December 2029
		Telecom Italia	December 2029
		Vodafone	December 2029
		Iliad	December 2029

	2.1GHz FDD	Wind Tre	December 2029
		Telecom Italia	December 2029
		Vodafone	December 2029
		Iliad	December 2029
	2.6GHz FDD	Wind Tre	December 2029
		Telecom Italia	December 2029
		Vodafone	December 2029
		Iliad	December 2029
	2.6GHz TDD	Wind Tre	December 2029
	3.5GHz TDD	Wind Tre	December 2037
		Telecom Italia	December 2037
		Vodafone	December 2037
		Iliad	December 2037
	26GHz TDD	Wind Tre	December 2037
		Telecom Italia	December 2037
		Vodafone	December 2037
		Iliad	December 2037
		Fastweb	December 2037
Latvia	900MHz FDD	Bite	June 2030
		LMT	January 2026
		Tele2	February 2026
		Tele2	September 2028
	1800MHz FDD	Bite	June 2030
		LMT	January 2026
		Tele2	February 2026
	1900MHz TDD	Bite	June 2030
		LMT	June 2030
	2.1GHz FDD	Bite	June 2030
		LMT	June 2030
		LMT	December 2027

		Tele2	December 2027
	2.3GHz TDD	Bite	December 2027
		LMT	December 2027
	2.6GHz FDD	Bite	December 2028
		LMT	December 2028
		Tele2	December 2028
	2.6GHz TDD	LMT	December 2028
	3400MHz TDD	LMT	December 2028
		Tele2	December 2028
		Unistars	December 2028
		Telia	May 2025
Lithuania	800MHz FDD	Bite	July 2030
		Telia	July 2030
		Tele2	July 2030
	900MHz FDD	Bite	October 2032
		Telia	October 2032
		Tele2	October 2032
	1800MHz FDD	Bite	October 2032
		Telia	October 2032
		Tele2	October 2032
	2.1GHz FDD	Bite	February 2026
		Telia	February 2026
		Tele2	March 2026
	2.3GHz TDD	Lithuanian Radio and Television Center	July 2029
	2.6GHz FDD	Bite	August 2027
		Telia	August 2027
		Tele2	August 2027
		Lithuanian Radio and Television Center	January 2030
	2.6GHz TDD	Lithuanian Radio and Television Center	January 2030

	3.5GHz TDD	Lithuanian Radio and Television Center	October 2022
		Lithuanian Radio and Television Center	July 2027
Luxembourg	800MHz FDD	Post	December 2027
		Proximus	December 2027
		Orange	December 2027
	900MHz FDD	Post	May 2027
		Proximus	May 2027
		Orange	June 2027
	1800MHz FDD	Post	May 2027
		Proximus	May 2027
		Orange	June 2027
	2.6GHz FDD	Post	December 2027
		Proximus	December 2027
		Orange	December 2027
Malta	900MHz FDD	Melita	August 2026
		GO	August 2026
		Epic	August 2026
	1800MHz FDD	GO	August 2026
		Epic	August 2026
	1900MHz TDD	Melita	August 2022
		GO	August 2022
		Epic	August 2022
	2.1GHz FDD	Melita	August 2022
		GO	August 2022
		Epic	August 2022
Netherlands	800MHz FDD	T-Mobile	December 2029
		Vodafone	December 2029
		KPN	December 2029
	900MHz FDD	T-Mobile	February 2030

		Vodafone	February 2030
		KPN	February 2030
	1800MHz FDD	T-Mobile	December 2029
		T-Mobile	February 2030
		Vodafone	February 2030
		KPN	February 2030
	2.6GHz FDD	T-Mobile	May 2030
		Vodafone	May 2030
		KPN	May 2030
		ZUM	May 2030
	2.6GHz TDD	T-Mobile	December 2029
		KPN	December 2029
Norway	1800MHz FDD	Telenor	December 2028
		Telia	December 2028
	2000MHz TDD	Inquam	December 2022
	2.1GHz FDD	Telenor	December 2032
		Telia	December 2032
		Ice	December 2032
	2.3GHz TDD	Telenor	December 2022
		TV 2	December 2022
		Norwegian Broadcasting Corporation	December 2022
	2.6GHz FDD	Telenor	December 2022
		Telia	December 2022
		Simula Metropolitan Center for Digital Engineering	December 2022
	2.6GHz TDD	Cayman Spectrum	December 2022
	3400MHz TDD	Telenor	December 2022
		Telia	December 2022
		NextGenTel	December 2022

		40 regional licences	December 2022
	26GHz TDD	Telenor	December 2022
		Telia	December 2022
		Statnett	December 2022
		GlobalConnect	December 2022
		GlobalConnect	December 2024
		2 regional licences	On or before December 2024
Poland	900MHz FDD	P4	December 2023
		Aero 2	December 2023
		Polkomtel	February 2026
		T-Mobile	February 2026
	1800MHz FDD	Centernet	December 2022
		Mobyland	December 2022
		P4	December 2027
		T-Mobile	December 2027
		Orange	August 2027
	1900MHz TDD	P4	December 2022
		Polska Telefonia Cyfrowa	January 2023
		Orange	January 2023
	2.1GHz FDD	P4	December 2022
		Polkomtel	January 2023
		Orange	January 2023
	2.6GHz TDD	Aero 2	December 2024
Portugal	800MHz FDD	MEO	March 2027
		Vodafone	March 2027
		NOS	March 2027
	900MHz FDD	MEO	March 2022
		Vodafone	March 2027
		NOS	November 2027

	1800MHz FDD	MEO	March 2022
		MEO	March 2027
		Vodafone	March 2027
		NOS	March 2027
	2.6GHz FDD	MEO	March 2027
		Vodafone	March 2027
		NOS	March 2027
	2.6GHz TDD	Vodafone	March 2027
	3.5GHz TDD	2 regional licences by Dense Air	August 2025
Romania	800MHz FDD	Telekom Romania	April 2029
		Vodafone	April 2029
		Orange	April 2029
	900MHz FDD	Telekom Romania	April 2029
		Vodafone	April 2029
		Orange	April 2029
		RCS-RDS	April 2029
	1800MHz FDD	Telekom Romania	April 2029
		Vodafone	April 2029
	2.6GHz FDD	Orange	April 2029
		Telekom Romania	April 2029
	2.6GHz TDD	2K Telecom	April 2029
		Vodafone	April 2029
Slovakia	800MHz FDD	Slovak Telekom	December 2028
		Orange	December 2028
		O2	December 2028
	900MHz FDD	Slovak Telekom	December 2028
		Orange	December 2028
		O2	September 2026
		O2	December 2028
	1800MHz FDD	Slovak Telekom	December 2025

		Orange	December 2025	
		Orange	September 2026	
		O2	December 2025	
		O2	September 2026	
		Swan	December 2025	
		Swan	September 2026	
	2.1GHz FDD	Slovak Telekom	August 2026	
		Orange	August 2026	
		O2	September 2026	
	2.6GHz FDD	Slovak Telekom	December 2028	
		Orange	December 2028	
	2.6GHz TDD	Slovak Telekom	December 2028	
	3.5GHz TDD	Orange	December 2024	
		Orange	August 2025	New licence issued
		O2	December 2024	
		O2	August 2025	New licence issued
		Slovanet	August 2025	New licence issued
Slovenia	800MHz FDD	Telekom Slovenije	May 2029	
		Telemach	May 2029	
		A1	May 2029	
		Telekom Slovenije	January 2031	
		Telemach	January 2031	
		A1	January 2031	
	1800MHz FDD	Telekom Slovenije	January 2031	
		Telemach	January 2031	
		A1	January 2031	
	2.6GHz FDD	Telekom Slovenije	May 2029	
		A1	May 2029	
	3.5GHz TDD	1 regional licence	November 2022	

Spain	800MHz FDD	Vodafone	April 2031
		Orange	April 2031
		Telefónica	April 2031
	900MHz FDD	Vodafone	January 2028
		Vodafone	December 2030
		Orange	December 2030
		Telefónica	December 2030
	1800MHz FDD	Vodafone	December 2030
		Orange	December 2030
		Telefónica	December 2030
		Xfera	December 2030
	2.6GHz FDD	Vodafone	December 2030
		Orange	December 2030
		Telefónica	December 2030
		39 regional licences	December 2030
	2.6GHz TDD	Vodafone	December 2030
		Orange	December 2030
		Aire Networks	December 2030
		15 regional licences	December 2030
Sweden	900MHz FDD	Hi3G	December 2025
		Net4Mobility	December 2025
		Tele 2	December 2025
		Telenor	December 2025
		Telia	December 2025
	1800MHz FDD	Net4Mobility	December 2027
		Telia	December 2027
	2.1GHz FDD	Hi3G	December 2025
		Telenor	December 2025
		Svenska UMTS-Licens	December 2025
	2.6GHz FDD	Hi3G	December 2023

		Net4Mobility	December 2023
		Telia	December 2023
	2.6GHz TDD	Hi3G	December 2023
	3.5GHz TDD	TDC	December 2022
		3 regional licences	December 2022
Switzerland	800MHz FDD	Sunrise	December 2028
		Swisscom	December 2028
		Salt	December 2028
	900MHz FDD	Sunrise	December 2028
		Swisscom	December 2028
		Salt	December 2028
	1800MHz FDD	Sunrise	December 2028
		Swisscom	December 2028
		Salt	December 2028
	2.1GHz FDD	Sunrise	December 2028
		Swisscom	December 2028
		Salt	December 2028
	2.6GHz FDD	Sunrise	December 2028
		Swisscom	December 2028
		Salt	December 2028
	2.6GHz TDD	Swisscom	December 2028

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